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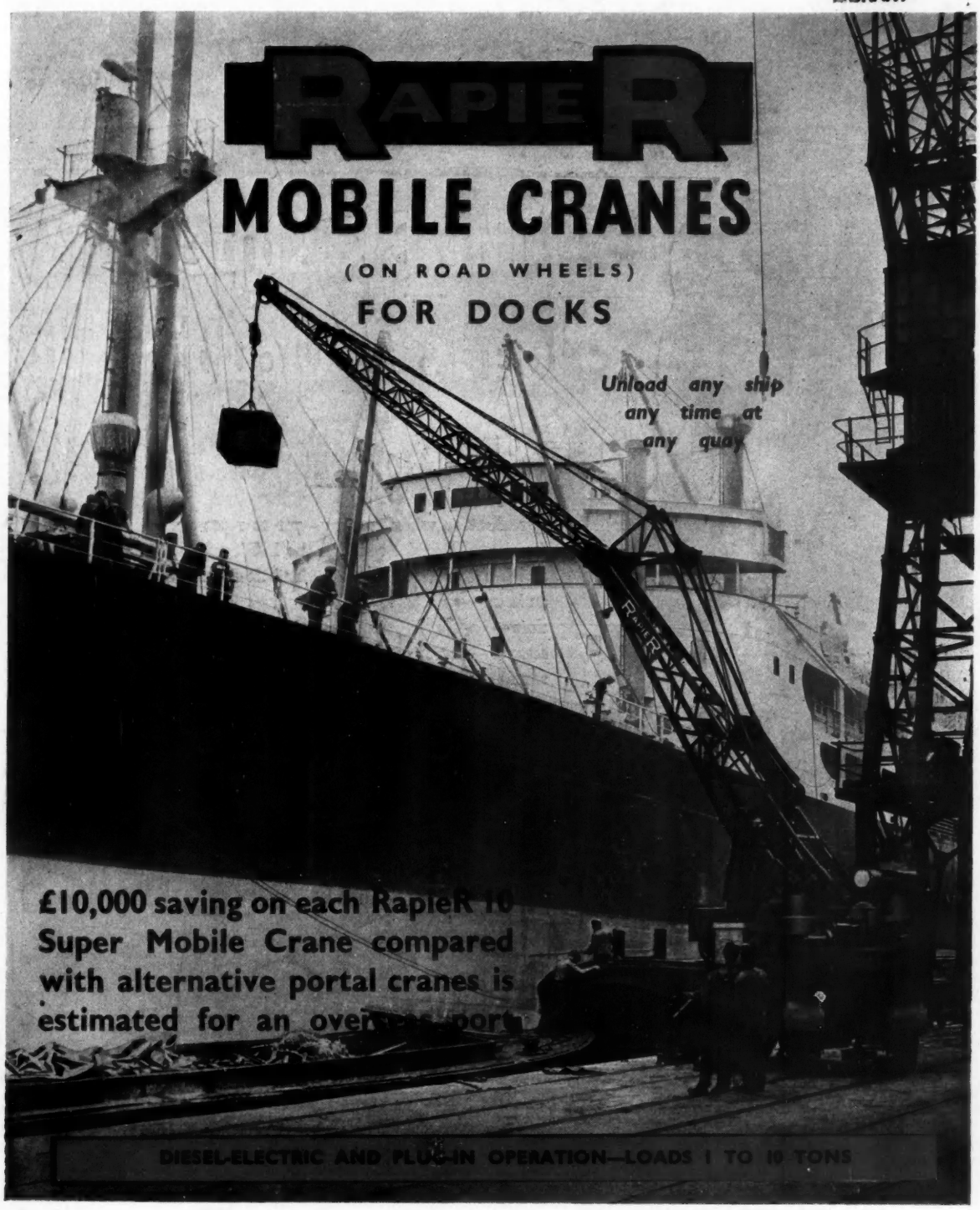
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THE ENGINEER

MARCH 4, 1955

Institution of Electrical Engineers

THE annual dinner of the Institution of Electrical Engineers was held at Grosvenor House on Thursday, February 24th, with the president, Mr. J. Eccles, in the chair. The toast of "The Institution" was proposed by the Rt. Hon. Sir Raymond Evershed, Master of the Rolls, who reminded the assembly that the I.E.E. was two years older than the Supreme Court of Judicature and two years older than income tax. The electrical engineer, he said, should not forget, in his preoccupation with his studies, that a knowledge of that particular branch of applied science was but a part of the sum total of human knowledge; to render service to mankind the profession should reflect the spiritual and emotional side of human endeavour. In his response to the toast Mr. Eccles reiterated the need for more scientists and engineers and he referred, in particular, to the great dearth of science teachers in schools. These shortages could be met by providing better remuneration and prospects for science teachers; by the Minister of Education providing a sound basis for the future pattern of technical education; and by parents encouraging their children to adopt a scientific career. If the need was for men of quality, it was extremely important that the Government in its plans for technical education should insist upon a comprehensive course, including mathematics, physics and chemistry, as well as the requisite engineering technology, to be provided in adequately equipped and competently staffed colleges. Indeed, the content of the course and the quality of the college were of far greater importance than the title of the award. The three major engineering institutions—the Institution of Civil Engineers, the Institution of Mechanical Engineers and the Institution of Electrical Engineers—believed that it would be a disservice to the country to lower their requirements for membership. Since corporate membership of those learned bodies conferred professional status, they could not concur in any proposal which might create a crop of sub-standard young men who, though classing themselves as engineers, might not qualify for membership. The institutions were also doing something to broaden the outlook of the technologist beyond his narrow professional interests, so that he might take his place at every level in the government of his country, his business organisation and, not least, in the community in which he lived. The toast of "Our Guests" was proposed by Mr. Harold Bishop, immediate past-president of the Institution, and the response was made by Lord Citrine, chairman of the British Electricity Authority.

Development of Geothermal Power and Heavy Water in New Zealand

A COMPANY known as Geothermal Development, Ltd., in which the New Zealand Government and the United Kingdom Atomic Energy Authority are the sole shareholders, has been formed to undertake the production of heavy water and electric power from geothermal steam in the Wairakei district of North Island, New Zealand. It was first announced in July of last year that the United Kingdom and New Zealand Governments had agreed to proceed with such a project "in view of the prospects of utilising heavy water in certain types of nuclear power reactors," and the project has since been studied in New Zealand and in the Atomic Energy Research Establishment, Harwell, in collaboration with Messrs. Merz and McLellan (consultants to the New Zealand Government on electric power) and Head, Wrightson Processes, Ltd. (consultants to A.E.R.E. on heavy water). The new company will employ the New Zealand Ministry of Works as its construction agent. Loans for the heavy water plant (estimated at £2,000,000) are to come from the Authority and those for the electric power equipment (estimated at £4,000,000) from the New Zealand Government. The board of directors comprises three representatives of the New Zealand Government and two from the United Kingdom Atomic Energy Authority. The first directors are: from the Authority, Sir Donald Perrott (member for finance and administration) and Mr. A. S. White (head of the chemical engineering division at Harwell); and from the New Zealand Government, Mr. B. C. Ashwin (Secretary of the Treasury (Chairman)); Mr. A. E. Davenport (general manager, State Hydro-Electric Department), and Mr. C. W. C. Turner (engineer-in-chief, Ministry of Works). Dr. E. Marsden, a former head of the New Zealand Department of Scientific and Industrial Research, will be associated with the Board. It is envisaged that production of heavy water will begin late in 1957 and of electric power a few months later. The initial plant will have an installed capacity of about 40MW, and will produce a "useful tonnage of heavy water for nuclear power reactors." Boring and development work at Wairakei has already begun, and tenders are being sought for the principal turbo-electrical machinery. Geothermal power has been used in Italy for many years, and power generation to the extent of 280MW has been achieved in the Lardarello area. The geothermal conditions, however, are different from those encountered in New Zealand.

Tin Research

THE annual report of the International Tin Research Council for 1954 was published last week. Among the main subjects of research at the Institute's laboratories in Greenford, Middlesex, during the year were the newly perfected bearing alloys made of aluminium-tin alloy. Bearings made from steel strip coated with a thin layer of aluminium-tin alloy will be the main application, the difficulty of securing a strong bond between these two materials having been overcome. The laboratory tests indicate, according to the report, that even at loadings of 6000 lb per square inch these bearings have excellent running properties. Commercial development is under way in this country. Further studies were made of the formation of tin-iron alloy upon tinplate during flow brightening, and a new chemical test for assessing the liability of tinplate to rusting and corrosion has been established. It is noted in the report that two electroplated alloys invented at the Institute are now coming into widespread use. The tin-zinc alloy electroplate is a matt finish for steel, and details of this finish are now available in the Ministry of Supply's Specification D.T.D. 927. The tin-nickel alloy electroplate, on the other hand, is intended for all metals requiring a permanent brilliant finish. Organo-tin compounds are being investigated for their possible applications in the preservation of wood, paper, textiles, &c., against fungi, moulds and insects. It is hoped that organo-tin compounds may be synthesised and used for plant protection.

Radioactive Experiments on Thames Mud

RADIOACTIVE ground glass has been used by the Hydraulics Research Station, D.S.I.R., we are informed, in collaboration with the Atomic Energy Research Establishment, in a small-scale experiment in the River Thames. The glass, containing radioactive scandium oxide, was injected into the river at Gravesend. The object of the experiment was to see if it were possible to trace the movements of mud on the river bed. For some time it has been suspected that the dredged mud from the river channel and dock areas of the Port of London, most of which is dumped at sea beyond the estuary, is being carried back again up the river by the tide. It was difficult to prove or disprove the theory until the movements of the mud could be tracked in some way. Any material put into the river had to behave as much like the mud as possible. Glass, ground so that its particle size was similar to that of Thames mud, was found to be suitable for the purpose. Scandium oxide was incorporated into the glass and the whole irradiated in the atomic pile at Harwell to form the isotope scandium 46, which is a suitable radioactive tracer. Special equipment was necessary to inject the material into the Thames. It consisted of a drum with its ends spring loaded so that they could be opened by pulling a release wire. Into this the scandium glass, mixed with river mud, was placed and the drum was lowered to the bottom of the river. When the ends were opened the water washed the contents out. The injection was done in mid-channel, at Gravesend, at low slack water. Searches for radioactivity took place for several days afterwards, using Geiger counters in a waterproof container. The results showed that the method was a feasible one, although the grains of glass could not be followed while moving but only located when they were stationary on the river bed. Some of the material was carried at least 2 or 3 miles upstream in the first few tidal cycles. It is very likely that, on the fifth day after injection, some of it was 11 miles upstream and small amounts as far as 16 miles. The quantity injected in the river, however, was so small that no opinion about the movements of the mud could be based on these results, which proved only that the method was a possible one and could be used in a large-scale experiment from which more conclusive information might be expected.

Landing Aid for Fleet Air Arm

As a further contribution to the safe landing of aircraft on to the flight deck of aircraft carriers, a new sound device for indicating air speed has been developed for the Admiralty by the Royal Air Force Institute of Aviation Medicine, and the Ministry of Supply's Royal Aircraft Establishment, both at Farnborough. Known as Audio, it works on the principle of an electric organ and gives its assurance as to correct speed and warning of incorrect speed in the pilot's earphones as a background signal. Tests had shown that for this particular landing operation in bad weather the pilot's saturation point in the visual field had been nearly reached. Using the stabilised mirror landing aid, the task for the pilot falls under three main headings: alignment with the centre of the landing lane; maintenance of the aircraft in the correct height band by reference to the mirror, and adjustment of the airspeed to within certain narrow limits by visual reference to an air speed indicator, usually placed inside the cockpit. Pilots carrying out the initial trials of the mirror landing aid used artificially high closing speeds and they reported that they experienced difficulty in fulfilling all three of these tasks simultaneously. This resulted in attention being concentrated on two of the tasks to the detriment of the third. Possibly because of the remoteness of the air speed indicator, it was air speed usually that was neglected. The Audio apparatus is particularly pleasant to use during a ground control approach as the signals can be heard as an informative background to the controller's instructions. The apparatus is relatively simple, is accurate to within a quarter of a knot, and there are no valves. It is made in two separate parts which can be put anywhere in the aircraft. One of the parts consists of a "sensing" unit to be attached to the pitot head, the other is the sound-producing box, consisting of a "two-note organ," working on the same principle as an electric organ. A camera recorded eye movements of pilots and two facts emerged during approaches and landings. Using the Audio airspeed, very few visual references were made to the conventional air speed indicator. Pilots resumed a normal rate of blinking during the approach where formerly they had ceased blinking.

Electronic Calculation of Critical Whirling Speeds

By C. F. GRADWELL, M.A., and Miss J. KAYE, B.Sc.

*Some of the work on the computation of critical speeds of rotor systems that has been done on the Ferranti electronic digital computer at Manchester University is described here. The mathematical method is described, and some explanation is given of how the computer is used to carry out the computation. No detailed description of the computer itself is given, as this information is already obtainable from many other sources.**

THE problem of computing critical speeds is an important one to manufacturers of rotating machinery. For efficient design, where several alternative forms have to be considered in succession, it is vitally necessary to have some convenient method to hand whereby the required calculations may be rapidly performed. This has been made possible by the advent of electronic computing machinery.

Basic Theory

We assume that the preliminary work of reducing the given system to a mathematical idealisation has already been done. This in itself may be no easy task, but at present it is not amenable to treatment by automatic methods, since it involves an intimate knowledge of the detailed construction of the system that is being studied. In the mathematical model of the given rotor, the weight of any shaft section is concentrated into discs at its two ends ; the model thus consists of any number of discs connected by weightless lengths of shafting, any of which may contain bearings (see Fig. 1). The critical speed programme is general enough to treat any desired arrangement of bearings and discs, provided only that the number of discs does not exceed

Fig. 1—Mathematical model of rotor

sixty, and that two bearings do not occur without an intervening disc. Another minor limitation is that the stiffnesses of the shaft sections on both sides of a bearing (if not at the end of the rotor) must be the same.

The bearings are assumed to provide rigid point-support only, i.e. they do not restrict the angular motion of the shaft (as distinct from the rotational motion of the shaft as a whole). Each disc is allowed two degress of freedom : an upward deflection y, and an angular deflection θ in an anticlockwise direction about a horizontal diameter (Fig. 2).

The mathematical operations required in the following analysis are very simple ones, and consist mainly of the manipulation of small matrices and vectors. The theory used is based on the concept of matrix influence coefficients, which define the elastic interaction between one disc and another.

For this purpose the discs are numbered 1, 2. . . . n, starting at the left-hand end, there being n discs. The lateral and angular deflections of the i-th disc are denoted by y_i and θ_i respectively, and the two may be written together in vector form, thus : $u_i=\{y_i,\ \theta_i\}$. (Scalar, vector and matrix symbols will be printed without distinguishing features.)

We shall speak of u_i as the (generalised) deflection of disc i. Forces and moments on disc i will be denoted by P_i (a force in the positive y direction), and M_i (a moment in the positive θ direction).

These also may be written in vector form $F_i=\{P_i,\ M_i\}$. F_i is the (generalised) force on disc i.

We are now in a position to define the matrix influence coefficient A_{ij}, which is a square matrix of order 2. Suppose the deflection of disc j is u_j, and that all other

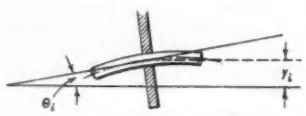


Fig. 2—Deflections y_i and θ_i of disc i

deflections are zero. To achieve this state of affairs, certain external forces will have to be applied to all the discs. If we say that the force which has to be applied to disc i is $F_i=A_{ij}u_j$, then here we have a unique definition of the matrix A_{ij}. If disc i is not a neighbour of disc j, the matrix will, of course, be zero.

We consider now the inertia forces on disc i. If the rotational speed (or the circular frequency of vibration) is ω rads. per sec., there will be an inertia force of magnitude $\omega^2m_iy_i$, where m_i is the mass of disc i. Similarly, if the gyroscopic effect is taken into account, there will be a couple of magnitude $-\omega^2b_i\theta_i$, where b_i is the moment of inertia about a diameter of disc i. Thus the inertia loading may be expressed in the vector form $\omega^2M_iu_i$ where M_i is the matrix $\begin{pmatrix} m_i & 0 \\ 0 & -b_i \end{pmatrix}$, a square matrix of order 2.

Equations of motion may now be written down for a rotor vibrating in one of its normal modes. There is one matrix equation for each disc, representing a zero total of inertia and elastic forces.

$$\left.\begin{aligned} A_{11}u_1+A_{12}u_2 &= \omega^2M_1u_1 \\ A_{21}u_1+A_{22}u_2+A_{23}u &= \omega^2M_2u_2 \\ A_{32}u_2+A_{33}u_3+A_{34}u_4 &= \omega^2M_3u_3 \\ \cdots\cdots\cdots\cdots & \\ A_{n(n-1)}u_{n-1}+A_{nn}u_n &= \omega^2M_nu_n \end{aligned}\right\} \quad (1)$$

These n matrix equations may now be solved for the critical speeds and the appropriate modal deflections. The description of how this is done is deferred until more has been said about the influence coefficients.

Influence Coefficients

All these coefficients may be built up by considering three different elementary cases of beam deflection.

In Fig. 3 there is a deflection $u=\{y, \theta\}$ at the right-hand end in each case, and we require the forces and moments (in terms of u) which are needed at the points marked A, B, C, D, E.

If the generalised force at A is written in the form $F=a\,u$, then from simple beam bending theory we have :

$$a=\frac{EI}{l^3}\begin{pmatrix} -12 & 6l \\ -6l & 2l^2 \end{pmatrix},$$

where EI is the stiffness, and l the length.

Similarly for b and c :

$$b=\frac{EI}{l^3}\begin{pmatrix} 12 & -6l \\ -6l & 4l^2 \end{pmatrix} \text{ and } c=\frac{EI}{l^3}\begin{pmatrix} 3 & -3l \\ -3l & 3l^2 \end{pmatrix}.$$

The expressions for d and e are a little more complicated.

$$d=\frac{EI}{l_1l_2(l_1+l_2)}\begin{pmatrix} 9 & -3l_2 \\ 3l_1 & -l_1l_2 \end{pmatrix},$$

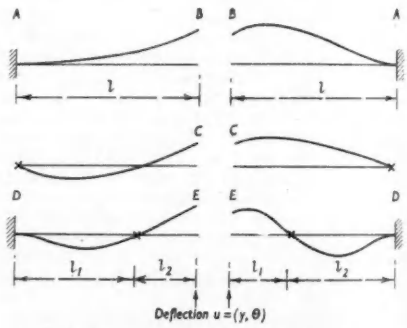
$$e=\frac{3EI}{l_2^3(l_1+l_2)}\begin{pmatrix} e_{11} & e_{12} \\ e_{21} & e_{22} \end{pmatrix},$$

where

$$\begin{aligned} e_{11}&=l_1+4l_2, \\ e_{12}&=-l_2(l_1+2l_2), \\ e_{21}&=-l_2(l_1+2l_2), \\ e_{22}&=l_2^2(l_1+4l_2/3). \end{aligned}$$

The matrices $a. \ . \ . \ . \ .e$ may be termed "basic force matrices." Also required are five similar matrices which correspond to reflections of the above three cases of beam bending in Fig. 3 about the right-hand ends. These reflections are shown in Fig. 4. The matrices corresponding to $a. \ . \ . \ . \ . \ . \ .$ will be denoted by $\bar{a} \ . \ . \ . \ .$, and it is easily seen that to obtain, say $\bar{a}$ from a, it is only necessary to reverse the signs of the off-diagonal terms. In the case of d and e, however, it is also necessary to interchange l_1 and l_2.

The next stage is to evolve an automatic process for taking into account the various arrangements of bearings and discs that may



Figs. 3 and 4—Basic force matrices (left). Basic force matrices, reflected (right)

occur in practice. We start with the bearing number system. Assuming that there are n discs and m bearings, we number the bearings and discs $j=1, 2, 3, \ldots n+m$, starting at the left-hand end, without regard to any distinction between bearing and disc. This enables us to define a function i of j :—

If j represents a bearing, $i=-1$.

If j represents a disc, i=serial number of disc. Thus, for the rotor shown in Fig. 1, the computer would store a table of the form

$j=$	1	2	3	4	5	6	7	8	9
$i=$	−1	1	2	3	−1	4	5	6	−1

It is also necessary to number the shaft sections. They are numbered $s=1, 2, \ldots n+m-1$, again starting at the left-hand end.

The basic force matrices $a \ . \ . \ .$ may have to be computed for any of the $n+m-1$ shaft sections. If a is computed for section s it will be denoted by $a(s)$. Similarly, if d, say, is computed for neighbouring sections s, t, it will be denoted by $d(s, t)$; i.e. the lengths l_1, l_2 to be used in the formula for d are those

* Symposium of papers on Digital Computers, *Proc. I.E.E.* 100, Part II, No. 77, October, 1953.

corresponding to sections s, t respectively.

We may now summarise the five tables that have to be stored in the machine ; these numerical data are fed into the machine on five-hole teleprinter tape.

Table No.	Purpose
1 ...	Bearing list, i.e., function i of j for $j=1, 2 \ldots n+m$.
2 ...	List of disc masses, i.e. m_i for $i=1, 2 \ldots n$.
3 ...	List of disc inertias, i.e. b_i for the above i.
4 ...	List of shaft lengths, i.e. l_s for $s=1, 2 \ldots n+m-1$.
5 ...	List of shaft inertias, i.e., I_s for the above s.

The immediate problem may be stated as follows : to compute for the n values of i, the five matrices :

(1) $A_{i\,i-1}$,

(2) $A_{i\,i+1}$,

(3) $A_{ii}]_L$ (the force from the left),

(4) $A_{ii}]_R$ (the force from the right),

(5) $A_{ii}=A_{ii}]_L+A_{ii}]_R$.

For each i two simple quantities x and y have to be computed as follows. For the given i find from Table 1 the corresponding j. Again from Table 1 set x and y equal to the values of i corresponding to j values of $j-1$ and $j+1$. This simply means that if there is a bearing to the left (right) of disc i, $x(y)$ will be negative, otherwise $x(y)$ will be an appropriate disc number.

We are now in a position to write down the rules which enable the machine to determine the influence coefficient matrices.

(1) $A_{i\,i-1}=0$ if $i=1$
or $=\bar{a}(j-1)$ if $i>1$ and $x>0$
or $=\bar{d}(j-1, j-2)$ if $i>1$ and $x<0$.

(2) $A_{i\,i+1}=I$ (unit matrix) if $i=n$†
or $=a(j)$ if $i<n$ and $y>0$
or $=d(j, j+1)$ if $i<n$ and $y<0$.

(3) $A_{ii}]_L=0$ if $i=1$ and $j=1$
or $=c(1)$ if $i=1$ and $j=2$
or $=b(j-1)$ if $i>1$ and $x>0$
or $=e(j-2, j-1)$ if $i>1$ and $x<0$.

(4) $A_{ii}]_R=0$ if $i=n$ and $j=n+m$
or $=\bar{c}(j)$ if $i=n$ and $j=n+m-1$
or $=\bar{b}(j)$ if $i<n$ and $y>0$
or $=\bar{e}(j+1, j)$ if $i<n$ and $y<0$.

(5) $A_{ii}=A_{ii}]_L+A_{ii}]_R$.

The computation of the " A " matrices by a routine called " Influence Coefficients " is a necessary preliminary to the computation of whirling speeds proper. The basic force matrices $a \ldots$ are computed by a sub-routine which requires four pieces of data :

(1) a counter indicating which of the $a, \ldots$ to compute ;

(2) an index showing whether the " reflected " versions $\bar{a}, \ldots$ are required ;

(3) one number, or two numbers, indicating which lengths of shaft are referred to ; and

(4) the address in the stores where the matrix has to be written.

The function of the " Influence Coefficient " routine is to count through all the discs, to make the appropriate tests at each stage, and by calling in the " Basic Force Matrix" sub-routine, to compute for each disc the three matrices A_{ii-1}, A_{ii}, $A_{i\,i+1}$. It will be shown later that it is more useful to have the inverse of the last of these matrices, rather than $A_{i\,i+1}$ itself. The three matrices $A_{i\,i-1}$, A_{ii}, $A_{i\,i+1}{}^{-1}$ are written on the left-hand half of the track associated with disc i. Moreover, it is convenient to have the mass and inertia matrix M_i also on the same half track. Hence the effect of the " Influence Coefficient " routine is to produce on the left-hand halves of a series of tracks the matrices $A_{i\,i-1}$, A_{ii}, $A_i{}^{-1}{}_{i+1}$ M_i. It will be noted that under certain circumstances the matrix $A_{i\,i+1}$ is singular (due to the fact that the matrix d is singular). More will be said about this later ; we merely remark that in this case the matrix $A_{i\,i+1}$ is given without inversion, and is suitably " tagged."

† The reason for requiring $A_{n\,n+1}=I$ will appear later.

Because of the great importance of these matrices in the calculation of the whirling speeds, it is advisable that their calculation be checked. This is done by simple repetition, and using the special magnetic check facility which enables one to compare the contents of a storage tube with a half-track. Moreover, a " check-sum " of all the quantities involved is computed, so that if it is ever suspected that some of the quantities have changed their value, this suspicion may be confirmed or removed.

Solution of the Normal Mode Equations

The manner in which equations (1) are solved depends to some extent on the positions of the bearings. If there are only two bearings, and these are at the extremities of the rotor, then the solution is straightforward. In all other cases, one of the matrices $A_{i\,i+1}$ (being a " d " matrix) will be singular, and the simple solution must be modified somewhat.

We describe first the straightforward solution. This consists essentially of taking an arbitrary deflection u_1 for the first disc and computing for an assumed value of ω, deflections $u_2, u_3 \ldots u_n$ in terms of u_1. The last equation then gives a simple condition which must be satisfied if the assumed value of ω is to correspond to a critical whirling speed.

The first $n-1$ equations give :

$$\left.\begin{aligned} u_2 &= A_{12}{}^{-1}[\omega^2 M_1 - A_{11}]u_1 &&= X_2 u_1 \\ &\text{say} \\ u_3 &= A_{23}{}^{-1}[(\omega^2 M_2 - A_{22})X_2 - A_{21}]u_1 &&= X_3 u_1 \\ u_4 &= A_{34}{}^{-1}[(\omega^2 M_3 - A_{33})X_3 - A_{32}X_2]u_1 &&= X_4 u_1 \\ &\ldots\ldots\ldots\ldots\ldots\ldots \\ u_n &= A_{n-1,\,n}{}^{-1}[(\omega^2 M_{n-1} - A_{n-1,\,n-1})X_{n-1} \\ &\qquad - A_{n-1,\,n-2}\,X_{n-2}]u_1 = X_n u_1 \end{aligned}\right\} \quad (2)$$

Substituting in the final equation gives :

$$[(\omega^2 M_n - A_{nn})X_n - A_{n,\,n-1}\,X_{n-1}]u_1 = 0.$$

For a non-trivial u_1, we must have the determinant

$$|\,(\omega^2 M_n - A_{nn})X_n - A_{n,\,n-1}\,X_{n-1}\,| = 0,$$

which is the condition alluded to above.

This procedure may be tidied up for automatic computation as follows.

Introduce $X_0=0$ and $X_1=I$ (the unit matrix of order 2). We also require $A_{10}=I$, and $A_{n,\,n+1}=I$. From equations (2) we now obtain a simple matrix recurrence relation which expresses X_{i+1}, say, in terms of X_i and X_{i-1}.

$$X_0=0,\ X_1=I.$$

$$X_{i+1}=A_{i,\,i+1}{}^{-1}[(\omega^2 M_i - A_{ii})X_i - A_{i,\,i-1}\,X_{i-1}]$$

for

$$i=1, 2, 3 \ldots n.$$

The condition for a critical whirling speed is that the determinant $|\,X_{n+1}\,|$ vanish. Thus $|\,X_{n+1}\,|$, which is a polynomial of degree $2n$ in ω^2, may be computed for various values of ω until this condition is satisfied.

When a zero of $|\,X_{n+1}\,|$ has been found with sufficient accuracy, it then remains to compute the associated mode. To do this we use the equation $X_{n+1}\,u_1=0$; if the deflection y_1 be taken as unity, then the deflection θ_1 will be $-\alpha/\beta$, where α and β are the elements of the first row of X_{n+1}. Thus the deflection u_1 is determined (within an arbitrary factor), and the remaining u_2, $u_3 \ldots u_n$ may be got by substituting the known u_1 in the equations $u_2=X_2u_1$, &c. Hence it is advantageous if all the X_i matrices (for a given ω) are stored after they are computed, to avoid having to compute them again if necessary. This may be done conveniently by using the right-hand halves of the tracks on which the A and M matrices are written.

The iterative method used to determine the zeros of the determinant $D=|\,X_{n+1}\,|$ is the simplest one possible ; by each iteration, the interval containing the zero is reduced by a factor of one-half. This simple method may be used because the final answer need be correct to only one part, say, in a thousand. A more refined method would only be appropriate if greater accuracy were required, and more were known about the general behaviour of the function to begin with.

The procedure is as follows. Suppose it is known that the function D is positive at N_1 (N will henceforth denote a rotational speed in revolutions per minute) and negative at N_2. The machine will compute D at N_3, the mid-point of the range N_1N_2. The sign of D at this point determines whether the zero is in the interval N_1N_3 or N_3N_2. This

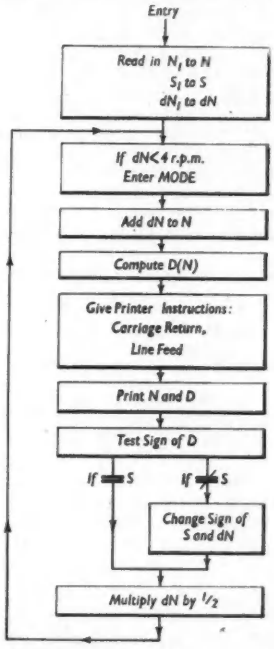


Fig. 5—Flow diagram of master routine

process is repeated until two successive iterates agree to closer than 4 r.p.m.

In practice, the computation is initiated as follows. Three items are read into the machine on tape :

(1) N_1, the initial value of N.

(2) S_1, the sign of D at N_1($S_1=+1$ for positive, -1 for negative).

(3) dN_1, a quantity equal to one-half the interval N_1N_2.

The " flow diagram " shown in Fig. 5 shows a logical break-down of the process. Speaking generally, this kind of diagram is the first stage in programming any operation for a digital computer. The second stage consists of writing the sets of detailed instructions which correspond to the various items on the flow diagram.

In the flow diagram, N, S and dN represent current values of speed, sign and interval, i.e. those which change for every iteration. The operations involved are mostly self-explanatory. The routine " Mode " referred to in the second block is the routine which computes the modal deflections of each disc and prints out the result. With regard to the input of S_1, this would, of course, be worked out by the computer, but

the present plan leads to an easier programme. Although it is possible for the operator to put the wrong sign into the machine, this would very soon become obvious from the printed results. For this scheme to be satisfactory, it is necessary that there should be a zero between N_1 and N_1+2dN_1. If the position of a zero is known approximately beforehand, this approximation may be speedily improved ; if not, a few sets of trial values of N_1, S_1 and dN_1 will generally indicate its rough position.

Modifications to the Basic Process

We now describe what modifications to the above scheme are required when (as often happens) the positioning of the bearings is such that one of the $A_{i,i+1}$ matrices is singular. In the case of the simple example shown in Fig. 1, the matrix A_{34} is singular and the third equation of the block of equations 2 becomes meaningless.

The six equations 1 are now solved in the following manner :

$$u_2=A_{12}^{-1}[\omega^2M_1-A_{11}]u_1=X_2u_1,$$
$$u_3=A_{23}^{-1}[(\omega^2M_2-A_{22})X_2-A_{21}]u_1=X_3u_1.$$

At this point, instead of expressing u_4 in terms of u_1, we express u_1 in terms of u_4 by means of the third equation.

$$u_1=[(\omega^2M_3-A_{33})X_3-A_{32}X_2]^{-1}A_{34}u_4=Y_3u_4 \text{ say.}$$

The next two equations give

$$u_5=A_{45}^{-1}[(\omega^2M_4-A_{44})Y_4-A_{43}X_3Y_3]u_4=Y_5u_4$$

(where $Y_4=I$),

$$u_6=A_{56}^{-1}[(\omega^2M_5-A_{55})Y_5-A_{54}Y_4]u_4=Y_6u_4,$$

while substituting in the sixth and last equation gives

$$[(\omega^2M_6-A_{66})Y_6-A_{65}Y_5]u_4=0.$$

The condition for a non-trivial u_4 is now that

$$|(\omega^2M_6-A_{66})Y_6-A_{65}Y_5|=0.$$

This is a condition similar to the one found previously, and may be treated similarly. That is, this determinant may be computed for various rotational speeds, and the zeros found. One important difference should be observed, however. In place of inverting the matrix A_{34}, the machine inverts the matrix $(\omega^2M_3-A_{33})X_3-A_{32}X_2$. This matrix itself will be singular for certain values of the rotational speed, and for these values, the final determinant will be infinite. That is, this determinant is no longer simply a polynomial, but a rational function. It may be shown that the poles of this function correspond to the critical speeds of a rotor similar to the one shown in Fig. 1, but modified so that only discs 1, 2 and 3 are allowed to vibrate (i.e. when discs 4, 5 and 6 are clamped).

Not only the zeros, but the poles also are computed by the master programme, and it is important that the two be distinguished. There is no difficulty here in practice since the printed results make it quite obvious whether the change of sign is accompanied by a zero or an infinity.

Conclusion

The following statements regarding times of the various sections will be of interest.

1. The routine "Influence Coefficients" computes (and checks) all the A and M matrices in approximately twelve seconds per disc.

2. The time required for computing and printing the value of D for a given rotational speed is 3·2 seconds per disc. About ten iterations are required in most cases before a sufficiently accurate solution is obtained.

3. The modal deflections are computed and printed in about 7·2 seconds per disc (most of this time being printing time).

In assessing the total time required for obtaining all the critical speeds of a given rotor up to a given maximum, there are two other factors to take into account. In the first place about 10–15 minutes (depending upon the size of the rotor) must be allowed for the input of the programme and the numerical data. Secondly, a certain amount of time must be allowed for "exploring" the function D; in particular, care must be taken not to miss pairs of zeros (if any) which are close together. This exploration time should not exceed one half of the useful computing time even in extreme cases, and generally, it should be much less.

The numerical data are fed into the machine on five-hole teleprinter tape. The time required for punching the tape may be judged from the fact that all the necessary double punching and verifying for a rotor of eighteen discs and three bearings has been done by each of the joint authors—neither of whom could be described as a skilled punch operator—in under an hour.

A simplification which often arises in practice is that the disc inertias may be neglected. This saves the punching and the input of Table 3 (disc inertias).

The authors are indebted to the British Thomson-Houston Company, Ltd., for providing them with details of practical rotor systems for numerical experimentation, and to Ferranti, Ltd., for permission to publish this article.

Investigation into the Failure of Two 100MW Turbo-Generators*

No. III—(*Continued from page 273, February 25th*)

By SIR CLAUDE GIBB, C.B.E., D.Sc., M.E., F.R.S.†

This paper describes investigations into the failure of two generators, each of 100MW capacity, installed in the Richard L. Hearn Generating Station at Toronto of The Hydro-Electric Power Commission of Ontario. The author details some general considerations affecting the design of alternator rotors, the selection of materials used, past troubles which had to be avoided, reasons for certain features incorporated in the original design and modified as the result of the failures, and safeguards introduced into current practice to avoid the possibility of a repetition of the failures.

It seemed important to ascertain why No. 4 exciter end bell failed similarly to Nos. 1 and 2 exciter end bells, whilst Nos. 2 and 3 turbine end bells cracked without the crack spreading, as had now occurred on three exciter end bells.

A critical examination of the two end bells which failed in service had revealed that after the failure twenty-four holes of No. 1 set exciter end bell showed minute surface cracks while No. 2 exciter end bell had sixty-eight holes with cracks. The most searching examination by boroscope and by the penetrant dye method failed to find any crack in any hole in the turbine-end end bells of Nos. 1 or 2 units, or in either end bell of Nos. 3 or 4 units before hydraulic testing. After failure by hydraulic pressure, however, No. 2 turbine end bell has twelve holes with minute surface cracks ; No. 3 turbine end bell had cracks in nine holes, and No. 4 exciter end bell had twenty-six holes showing cracks. After the cyclic testing to failure of the turbine end bell of No. 1 set (described later), three holes were found cracked, one crack extending from bore to outside, the other two cracks not extending to either inside or outside surface and obviously commencing at approximately mid-thickness of the bell which is the area of maximum stress. A large number of the cracks in each bell were sectioned and microphotographed and in every case the crack was intergranular, and in no instance was there any sign of stress corrosion.

Of the cracks found in the holes of the end bells which failed in service, it is not possible to say what proportion of them developed through the straightening out of the end bells which followed the failure. Some of them certainly conveyed the impression that they were due to the ovality of the holes produced by the straightening. All, however, were typical of cracks produced by overstress.

Of the five 37in end bells tested hydraulically, the one failing at a mean hoop stress of 42·92 tons per square inch was from a 60MW rotor which had been in service, whilst the two new drilled 37in bells were specially prepared under control conditions and at once tested hydraulically before any corrosion could possibly have taken place. These two bells failed quietly at a mean hoop stress of 40·70 and 41·69 tons per square inch.

Two new 37in bells were also prepared and tested hydraulically without ventilating holes being drilled. These began yielding at a mean hoop stress of 49·85 and 49·50 tons per square inch when the oil seals failed. Repeated attempts to maintain an oiltight seal at the pressure producing appreciable yield were unsuccessful. The amount of yield (expansion) at a mean stress approaching 50 tons per square inch was more than sufficient to have released the shrink on to the rotor body.

Several hundred hardness tests were made on the internal surface of holes using a 10 kg load with a Vickers diamond pyramid hardness tester. These showed variations from 351 to 657 while the parent metal away from holes ranged from 280 to 340. Thus, despite every care in drilling ventilating holes, there was considerable work hardening on the surface of the holes. This hardening appeared to have no relation to depth of hole, i.e. hardening was not progressive with depth. In many holes the hardness was lower at the bottom of the hole than at the beginning, but in general hardness was a maximum at or about the middle depth of the hole. The work-hardened skin of the hole was extremely thin and possible explanations are that the drill cuttings or swarf were rubbing the surface, sometimes causing surface polishing and at other times causing scratches, or that radial pressure of the drill was responsible.

An attempt was made to correlate hole surface hardness and polish with the area of incipient failure, but the results were contradictory. With No. 2 exciter end bell failure started from a hole with an exceptionally smooth and soft surface.

The stress applied in service to the Toronto end bells is 19¼ tons per square inch due to centrifugal loading of the copper and its own hoop stress. At the nose of the bell, where it is shrunk on to the rotor body, the stress is 26 tons per square inch when both rotor and bell are cold, but is appreciably less under normal operating temperatures when body and bell are warm because of the greater expansion coefficient of the austenitic material bell. The shrink stress could, however, be increased were the rotor body to be hot after coming off a high load and the end bell cold (or appreciably cooler) because of low-temperature cooling water being left flowing at full quantity to the hydrogen coolers. In such a case the greater expansion coefficient of the end bells would increase the shrink and thereby the stress.

The shrink stress of 26 tons per square inch is that resulting from the design ruling that the end bell shrink shall just loosen at 10 per cent above normal speed with rotor end bell at operating temperature. This ruling had been standard for many years and was a reasonable one decided by the desire to have no possible chance of end bell movement when the unit is taken to overspeed to test the emergency governor. As a result of the reconsideration of all design factors, a change has been made and the shrink stress reduced to 23 tons per square inch by reducing the speed at which the shrink loosens to 5 per cent above normal.

At this stage of the investigation it had been demonstrated that holes were undesirable, but the failures were not explained. Numerous test pieces cut from alongside the service failures merely confirmed the accuracy of the original acceptance tests and gave no clue to the cause of failure.

It was decided to put in hand repeated stress

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* Abstract of paper. Institution of Mechanical Engineers. London, February 15, 1955.

† Chairman and Managing Director of C. A. Parsons and Co., Ltd.

cycles by the hydraulic method to see what part fatigue played in the failure and also to make fatigue tests by the Wöhler method on samples of the end bell material. Izod tests at subnormal, normal and above normal temperatures were also made.

The cyclic pressure tests were carried out with the same apparatus as that used for the single loading pressure tests. The hydraulic pressure was built up to a specified level, maintained for five minutes, and then released. The cycle of loading and unloading was continued until the bell cracked or until the test was stopped for some other reason. The results obtained in this test are given in Table V.

The turbine end bell from No. 1 Toronto was raised to 27·6 tons per square inch. After 464 cycles of this range of stress the bell was cracked at hole No. 86 in Fig. 5 (*a*).

The test on the undrilled magnetic bell was carried out in order to confirm that the resistance of the replacement bells on the Toronto machines to repeated cycles of stress was better than that of the original bells. As this bell contained no holes, and was made from a different material from the other bells subjected to the cyclic test, it cannot be compared with them either from the point of view of showing the effect of holes or from that of showing the effect of the material.

The cracks produced in the cyclic tests were similar to those produced in the single loading pressure tests. There was no deformation of the

TABLE V—*Results of Cyclic Pressure Tests*

End bell	Maximum applied hoop stress, tons per sq in				Mean hoop stress, tons per sq in	Number of cycles
	Rotor body end		Balancing ring end			
	Inside	Outside	Inside	Outside		
Toronto No. 1 turbine end	28·35	25·72	26·42	23·83	27·6	76 failed
Toronto No. 4 turbine end	18·95	17·20	18·27	16·48	18·5	500
Toronto No. 4 turbine end	23·75	21·50	22·60	20·60	23·5	500
Toronto No. 4 turbine end	27·78	25·19	26·68	24·09	27·6	464 failed
Toronto magnetic bell, undrilled ...	—	—	—	—	30·0	924 not cracked
37in diameter end bell	28·07	24·32	27·13	23·38	25·59	174 failed

machine failed by cracking after it had been subjected to seventy-six cycles of stress over the range 0–27·6 tons per square inch. The crack occurred at a hole at the end of a row of three (i.e. No. 39 in Fig. 5 (*a*) *ante*), which is in a similar position to the holes at which the fractures began in the two bells that failed in service, and in the exciter end bell from Toronto No. 4 machine that fractured completely in the single loading pressure test. Two views of this crack are shown in Fig. 8 (*a*) and (*b*). Two other holes in this bell were found to be cracked, these being Nos. 39A and 37 in Fig. 5 (*a*). It will be noted that all the cracks in this end bell occurred in holes that were similarly disposed to those in which the fractures began in the two bells that failed in service and the exciter end bell from Toronto No. 4 machine that was fractured in the hydraulic test.

In view of the result obtained in the cyclic test on the turbine end bell from No. 1 Toronto machine, it was decided to endeavour to produce a crack in the turbine end bell from No. 4 Toronto machine by repeated applications of cycles of stress with a lower maximum. In the first instance this bell was subjected to cycles of stress arranged to give a maximum mean hoop stress of 18·5 tons per square inch. After 500 cycles the test was stopped and the bell examined for cracks in the holes. No cracks were found and the test was resumed but the maximum mean hoop stress of the cycle was raised to 23·5 tons per square inch. After 500 cycles of this range of stress the bell was again examined and, as no cracks were found in the holes, the test was again resumed, but the maximum mean hoop stress

material near the holes, but as the cracks extended away from the holes the material deformed in front of them. It seems clear that the failures were produced because cracks can be started at the surface of the holes under repeated applications of a lower stress than that required to start them in one application.

It will be seen that the turbine end bell from No. 4 machine gave a better performance in the cyclic test than that from No. 1 machine. It appears, however, that this difference is not substantial. There was an appreciable difference in the mean hoop stresses required to fail the three Toronto bells in the single loading pressure tests, and it does not seem that the difference in performance of the two bells in the cyclic test was any more significant than this. No two end bells are exactly alike and it is not to be expected that two bells selected at random would give identical results in a cyclic test. It is conceivable that one reason for the difference between No. 4 and No. 1 end bell may be associated with the fact that the better results on the one end bell were associated with the prestressing given by the cyclic test at the lower stresses. Furthermore, in addition to the differences between the two bells as produced they were in service for different lengths of time on different machines before they were tested, and this might have influenced their behaviour.

The results of the cyclic tests were so significant in relation to the Toronto failure that it was decided to carry out some cyclic tests on freshly machined and drilled 37in bells (Table V).

The disposition of the holes in these bells is shown in Fig. 5 (*b*) *ante*, which shows the position of the holes through which failure occurred in both static and cyclic tests in bells of this diameter.

In both the static and cyclic tests on the 37in bells a number of holes in the diagonal groups of seven were found to be cracked and no other cracks were found in holes outside of these groups. In all instances the cracks originated at the centre of the thickness.

The results of some Wöhler-type fatigue tests on specimens from two Toronto end bells are given in Table VI.

TABLE VI—*Results of Wöhler Fatigue Tests on Specimens from No. 2 Machine Turbine End Bell and No. 4 Machine Exciter End Bell Failed in Hydraulic Pressure Test*

No. 2 turbine end			No. 4 exciter end		
Stress range	No. of reversals	Result	Stress range	No. of reversals	Result
±21	10,480,300	Unbroken	±19	10,000,000	Unbroken
±23	10,000,000	Unbroken	±20	9,891,100	Broken
±24	4,359,900	Broken	±21	3,879,000	Broken
±25	1,884,000	Broken	±23	2,773,000	Broken
±27	651,900	Broken	±25	2,680,900	Broken

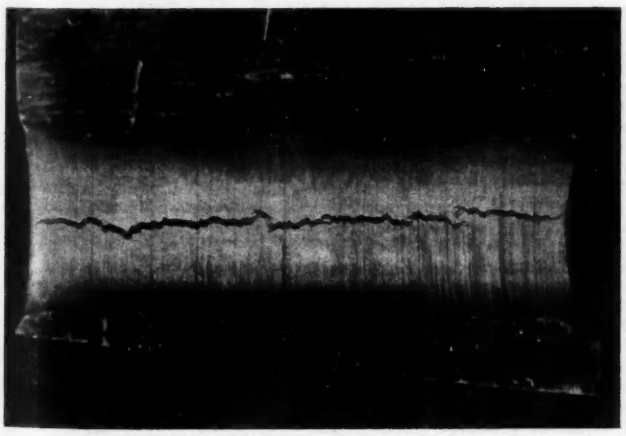
In addition to these results, there are the results of some similar tests on other specimens of end bell steel. Those results agree quite well with the results in Table VI, and on the basis of all the results it may be estimated that the fatigue limit of end bell steel under alternating stress (i.e. mean stress zero) is about ±21 tons per square inch. This figure is not relevant to the conditions realised in the cyclic tests in which cycles of repeated stress (i.e. mean stress equal to half the range of stress) were applied, but it does show that for end bell steel the ratio of the fatigue limit to the ultimate tensile strength is about 0·35, compared with 0·46 for heat-treated steels.

There are, however, the following results of Haigh fatigue tests on end bell steel in which cycles of repeated and fluctuating stress were applied :—

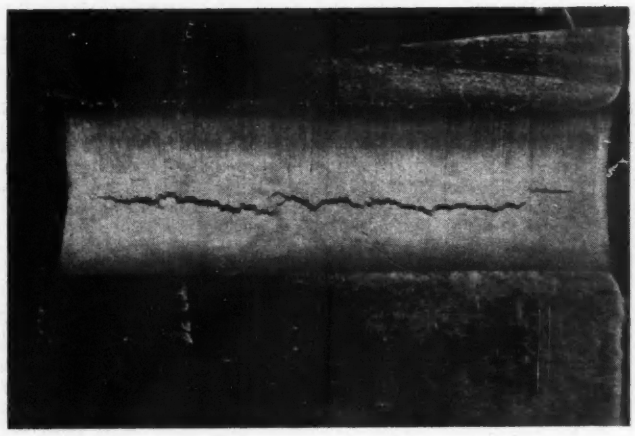
Mean stress, tons per sq in	Range of stress, tons per sq in	Cycles to fracture
17	±16·7	94,000
17	±12·1	1,618,000
17	±10·5	67,829,000 (unbroken)
17	± 9·5	33,334,000 (unbroken)

The drilled non-magnetic steel end bells were subjected to cycles of repeated stress that may be stated as mean stress 14 tons per square inch, range of stress ±14 tons per square inch. This range of stress is much less severe than the range that the Haigh specimen withstood for 94,000 cycles and should probably be compared with the range that the Haigh specimen withstood for 1,618,000 cycles. From this it appears that the performance of the end bells in the cyclic tests was very far below what would be expected from the available information on the fatigue properties of end bell steel under cycles of repeated stress. The fatigue tests were, of course, carried out on plain specimens without notches.

The general result of the cyclic tests on the



Side of hole nearer rotor body end (inner surface to the left).



Side of hole nearer balancing ring end (inner surface to the left).

Fig. 8 (a) and (b)—Toronto No. 1 unit, turbine end rotor end bell. Failed by seventy-six repeated applications of hydraulic pressure of mean hoop stress 27·6 tons per square inch

two end bells from the Toronto machines was to show that failure could be brought about under a relatively small number of cycles of stress of about the same order of magnitude as that applied in service.

It was evident that more information was required and further thought was given to one of the earliest suggestions made as to a possible cause. This was the effect of rapidly chilling the end bell while the rotor was at speed with rotor body and windings still relatively hot. Such a condition had occurred frequently in service. But it was desired also to ascertain whether, when the end bell was hot and therefore expanded more than the rotor body, with rotor end winding copper hard underneath the bell, and the bell then suddenly cooled and contracted, the end windings and their packings would arch bind and resist being forced to a smaller diameter—thus increasing end bell stress.

As a further means to resisting rotor coil distortion, rotor end windings frequently are packed solidly with a hard insulating material and the Toronto rotors had been so packed. Only by actual tests could arch binding be detected. A rotor from a 50MW generator was erected in an overspeed chamber with provision for heating the rotor body and subsequently cooling the end bell. Thermo-couples were attached to the rotor body, to the rotor windings, and to the end bell. These were brought out through the rotor bore to slip rings outside the bearing. Capacitance heads were mounted close to the end bell and were shown by calibration to be able to measure changes in bell diameter as small as one-thousandth of an inch. Cooling was by air drawn through a condenser in which refrigerated brine had been circulated for twenty-four hours before commencing the test. It was realised that the cooling effect of chilled air was far less than that of cold hydrogen at 10–15 lb per square inch pressure, but the dangers in using hydrogen would have been far too great to permit its use.

Measurements of the end bell dimension were taken at various speeds, both increasing and decreasing, and were found to agree with calculation. The amount of cooling of the end bell which could be achieved was relatively small and probably insufficient or too slowly achieved to produce arch binding if that could occur. The measurements taken did not indicate any lag in the end bell diameter returning to that which calculation and temperature indicated to be normal. Athough this difficult experiment gave only negative results, it was decided to ease the tightness of the packings in the replace rotors and in the modified rotors of Nos. 3 and 4 units.

Results of Izod tests on end bells at varying temperatures are given in Table VII.

Although these tests show a marked fall in impact value with temperature, within the range of service operating temperature, the reduction cannot be considered important or relevant to the investigation.

The second matter on which some concern had been felt related to the residual stresses in the bells. A certain amount of information was available relating to residual stresses on these rings prior to the Toronto failures, and the matter had been given some attention by the manufacturers. Two types of test to determine residual stresses in end bells were carried out :

(1) Destructive tests, in which successive layers of material were machined from the bore until 75 per cent of the cross-sectional area was removed, and Sach's method used to obtain the stress distribution over the section removed.

(2) Non-destructive tests, in which thin layers are machined from the bell up to 5 per cent of the cross section at the inner and/or outer surface. This gives an estimate of the stresses near the machined surface.

In all the tests electric resistance strain gauges were used to measure the deformation as the layers were removed. Deformation was measured in the axial and circumferential directions at the mid-length of the ring. Gauges were arranged in three, four or five groups equally spaced around the circumference. The calculation of stresses was based on the mean values of gauge readings and where large variation in the recorded strains of corresponding gauges occurred the mean of the more consistent strains was used.

Five end bells were tested by the destructive method and the calculated surface stresses in each are given in Table VIII.

End bells A, B and C in Table VIII were tested with the bells initially in the rough forged state. The results show high-tensile stresses ranging from 15 to 50 tons per square inch at the original bore. These stresses are reduced, when the bore is machined to the finished diameter, to about 10 tons per square inch compression in two bells, and to 7 tons per square inch tension in the third.

End bells D and E were already machined to final dimensions when tested. Compressive stresses of about 10 tons per square inch existed at the bores of both bells, with tensile stresses of 10 tons per square inch at the outer surface. The strain readings in these two bells show increasing "spread" as successive layers are removed and only the bore stresses may be considered to be approximately correct, i.e. within ±3 tons per square inch.

Non-destructive tests were carried out on thirteen end bells and when the results of one bell which gave two very high and, therefore, suspect tensile readings are rejected, the range nevertheless is from 19 tons per square inch compression to 39 tons per square inch tensile circumferentially, and from 18 tons per square inch compressive to 27·6 tons per square inch tensile longitudinally. All these figures relate to stresses in the material which was removed. No relation between the known amount of cold work applied and the residual stresses produced could be traced. Similar amounts of cold work gave either compressive or tensile bore stresses apparently quite fortuitously, and there did not appear to be any regular difference in residual stresses with yield points varying from 50 to 55·6 tons per square inch.

The calculations of residual stress are based upon a number of assumptions which, at the least, can be stated to be of doubtful validity. The destructive testing method almost certainly is more accurate than the non-destructive method, and it is obvious that much more development of the non-destructive test method is necessary.

While the numerical accuracy of the tests may be subject to doubt, they do nevertheless serve to warn the designer that, with the residual stresses likely to be either compressive or tensile in two apparently similar end bells, and of a magnitude likely to encroach seriously upon the estimated margin between calculated stress and safe working stress as determined from material acceptance tests, it is essential to reduce working stresses if that is possible, or to eliminate every form of stress raiser, or to change materials.

Reduction of working stresses in end bells is extremely difficult since approximately one-half of the total stress is that arising from its own mass with an almost equal amount due to the performance of the real function of an end bell which is to contain the rotor end windings. Thus, quite appreciably increasing the cross section of the end bell only relatively slowly reduces the stress, since the mean diameter of the bell and therefore the radius of gyration increase with thickness as well as mass.

To eliminate every form of stress raiser would preclude the use of ventilating holes and thus increase the rotor temperature rise and bring the rotor nearer to the point at which rotor coil distortion becomes a possible danger. If ventilating holes are retained they must be carefully ground after drilling, at least 0·04in of material removed and then subsequently the holes honed to a very fine finish.

(To be concluded)

TABLE VII—*Results of Izod Tests on End Bells*

(The numbers are values in feet-pounds)

End bell	Room temperature, deg. Cent.		
	−78	15	100
Toronto No. 1 exciter end failed in service	9 11	39 37 35	54 89
Toronto No. 2 exciter end failed in service	8 7	29 26 26	55 44
Toronto No. 2 turbine end failed pressure test	9 11	26 32 28	45 44
Toronto No. 4 exciter end failed pressure test	6 6	21 21 21	54 42

TABLE VIII—*Calculated Surface Stresses in End Bells*

Material	Treatment	Dimensions, inches			Circumferential stress, tons per square inch				Maximum longitudinal stress, tons per sq in	
		Outside diameter	Inner diameter	Length	Bore before machining	Bore after machining	Outer diameter before machining	Outer diameter after machining	Before machining	After machining
A— Non-magnetic : yield point, 50 tons per square inch ; ultimate strength, 55·6 tons per square inch	Cold worked 22 per cent	59·3	50·5	24·75	+40 to −50	+15 to +6	+8 to −16	+2 to −10	−17	−12
B— Non-magnetic	Cold worked	39·48	32·81	24	>−15	−7	+7	+4	+7	−7
C— Non-magnetic : yield point, 55 tons per square inch ; ultimate strength, 63 tons per square inch	Cold worked	55·03	47·75	33	−16	+10	−5	−7	>−20	+8
D— Non-magnetic	Stretched by hydraulic pressure	37·34	32·375	16·4	—	+4 to +8	—	−10	—	±4
E— Non-magnetic Toronto No. 3 exciter end...	Cold worked	58·44	53·19	20	—	+10	—	−10	—	−10

− Indicates tension. + Indicates compression.

Technical Report

An Investigation on Aluminium Electrolytic Capacitors and the Development of a New Type of Aluminium Oxide Capacitor (Ref. L/T305). By G. C. Robinson. The British Electrical and Allied Industries Research Association, Dorking Road, Leatherhead, Surrey, Price 7s. 6d., postage 3d.—The object of the investigation described in this report was to determine whether the working temperature range of aluminium oxide electrolytic capacitors could be extended. The minimum temperature at which electrolytic capacitors can be operated without serious loss of capacitance depends upon the conducting properties of the electrolyte at low temperatures, the electrolyte acting as a series resistance. It was known that the low temperature limit could be appreciably reduced by using special electrolytes which were more mobile and conductive than those normally used. With these special electrolytes, however, deterioration at elevated temperature and corrosion troubles were much increased. In Part I of the report different kinds of industrial electrolytic capacitors were examined, their temperature characteristics were determined and their performance under stress at elevated temperature was studied. Part II of the report is a fundamental study of the anodic forming process and of the properties of the oxide layer. It is shown that most of the current through the oxide occurs at a limited number of microscopic faults which, in the presence of an electrolyte and whilst under electric stress, are self-repairing but, in the absence of stress, eventually cause excessive conductance. This knowledge of current distribution has led to a new development of a dry aluminium oxide capacitor in which the faults are permanently cleared during manufacture or during subsequent use. This development, which is still in an early stage, is described.

Two Precast Concrete Structures

Two recent examples of the application of precast concrete techniques to structural work are described here. The eleven-storey block of flats at Wandsworth has a reinforced concrete structural frame, parts of which were precast, and part cast-in-situ to suit an erection schedule based on a large tower crane. The flour mill at Andover is being built with large precast concrete wall panels, precast beams, and in-situ columns. In both cases the construction time is short.

THE design and construction of tall blocks of flats is at present of topical interest in building circles, and such structures are now being included in the development schemes of a number of authorities. The subject of "Tall Flats" was discussed at a symposium held on February 15th at the Royal Institute of British Architects. During the course of this meeting, the economics of the construction of point blocks, eleven to fifteen or so storeys in height was discussed. Generally it was held that such flats cost appreciably more than corresponding accommodation in houses, but this assertion was challenged. Improvement in costs, it was thought, would be largely a matter of planning and of constructional technique. We give below a brief account of the methods used to build five eleven-storey blocks at Wandsworth; several stages in the erection of one of these blocks are illustrated herewith. Our description is abstracted from the remarks made at the R.I.B.A. Symposium by Mr. C. D. Mitchell, of Wates, Ltd., the contractors who built the blocks. They were designed by the architectural staff of the L.C.C., and the structural consultants were Ove Arup and Partners. Mr. Mitchell's remarks were as follows.

Eleven-Storey Flats at Wandsworth

Experience has shown that multi-storey flats usually take a long time to build. I hope to show that a marked advance in speed has been achieved. We cannot in this country claim to be experts in this field—we have a lot to learn from elsewhere, particularly America. I believe that the contractor has a lot to contribute in the planning of a job—his wide experience of plant, costs and technique is too often neglected. I am sure that there are many here to-day who have designed what they felt to be an easily built structure only to see their constructional conception disregarded by a contractor whose sole qualification is to be the cheapest in a nation-wide tender, who is then given a roll of drawings—often incomplete, sub-contractors with whom he has never worked before, and instructions to start on the site within seven days.

A firm step towards a more organised production was taken when we had the opportunity of building flats for the L.C.C. at Trinity Road, Wandsworth. The contract is one for five eleven-storey blocks of flats, each approximately 64ft square, with a reinforced concrete frame, clothed with an outer skin of 4½in brickwork, a cavity and a 3in clinker-block lining. Each block with its penthouse is about 120ft high and is planned with two lifts and two staircases. The whole job is centrally heated from an independent boiler house, the flue being housed in the first block. The total value is about £450,000 and the contract was obtained in limited competition.

Work to the foundations of the first block commenced in February, 1954, and to-day I am pleased to say that the first block is virtually completed, the second block is within a few weeks of handing over, the third block is plastered, the fourth block is half-clad externally with the reinforced concrete frame completed, and the last block has the reinforced concrete frame complete up to the seventh floor—all within twelve months. We expect to complete the whole contract by July—some four months earlier than the contract date.

In this case I felt the new French tower crane was the right tool for the job. The crane is self-erecting, is electrically driven, self-propelled on rails, has a mast height in its travelling position of 125ft, and in a fixed position it can extend to a height of approximately 300ft. The jib is horizontal, 65ft 6in long, fitted with a travelling bogey capable of lifting 3 tons at 15ft to a minimum of 17½ cwt at 65ft. The hoisting speed is 197ft a minute. The mast is extended by 22ft at a time by electrically-driven jacks embodied in the crane. Planning of the job centred around the crane and its capacity.

Accordingly, we considered precasting all the balcony slabs and all horizontal beams, thus eliminating practically all the intricate carpenters' work. We hoped to be able to pour the walls their full height, 8ft 2½in, using the largest possible shutters we could. This is where planning co-operation played its full and very important part. I am glad to be able to say that the architects, the engineer and the district surveyor, after due consideration, gave their full approval to my proposals and made one qualification—our proposals must not in any circumstances involve the client in any additional cost!

Having decided these important departures from the original design, the agent and site engineer were chosen for the job, and were brought into head office to play an important part in the contract planning. A scale model of a typical floor was made, showing clearly the parts to be precast and those to be cast *in situ*. The balconies and stairs were made off the site in a concrete works, but the beams were cast on the site, using the crane track as a casting bed. Landings as well as flights were entirely precast, and they came to the site complete with a high-grade granolithic finish. As each floor of the concrete structure was built, the landings and stairs were placed in position by the crane on precast concrete nibs cast into the side walls, and were then immediately protected by premade light timber casings. Access to each floor was thus immediately given. Balcony fronts were designed in one piece and could be placed in position on the precast balconies, the fixing bolts being grouted in position in preformed holes—a very quick and efficient solution.

Drawings for the large wall shutters were made, all electric conduit chases were shown, as well as all holes required. Several types of shutter were made experimentally at our plant depot, and, as a result, it was eventually decided to use 18mm plywood in sheets of 8ft by 4ft on 3in by 2in framing; where possible the shutter was of a size completely to shutter the wall for which it was to be used. All blockings for chases and holes were incorporated. In addition, a working platform for the concretors was fixed to each shutter, so that when placed in position both the shutter and the working access was provided. The shutters were held together by bolts passing between walings.

The flat slab shuttering was to be formed with telescopic shutters spanning in the main from wall to wall and covered with sheets of 8ft by 4ft plywood, each clearly numbered. These sheets were marked out to show position of ventilation ducts, holes through the floor, and the like, so it was important to place them floor by floor in the same position.

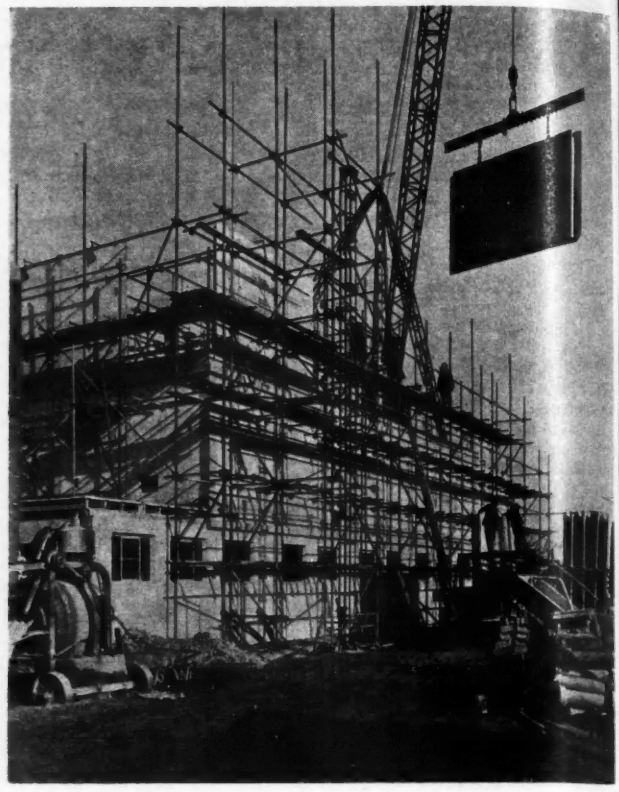
When examining the drawings for the reinforcing of the steel, it was noticed that a large number of links were required to separate the two vertical layers of reinforcement. Our suggestion to eliminate them and to substitute steel ladders made from ⅜in diameter uprights and ¼in diameter welded on at the correct centres was accepted, thus reducing the site labour.

For concreting, I decided to use our standard equipment for work of this kind, a 14/10 rotary drum mixer, a mobile weigh batching plant for the aggregates, fed by a trench crane equipped with a clamshell and mounted on a platform, a cement silo with automatic weighing equipment, fed by a pressurised tanker—equipment requiring only two men to operate. Specially designed buckets were made, one for use when filling 6in walls and columns, the other for use in the floors. The wall bucket was designed so as to sit nicely on top of the shutters with a protruding lip to direct the concrete straight in without spillage—each bucket takes the full discharge from the mixer.

It was planned to construct each floor of the concrete frame in seven working days, a time which was quickly reached and has been consistently improved upon, the best time so far being four and a half days; all this has been achieved with a gang of twenty-five men—five concretors, ten carpenters, five carpenters' labourers, four steel fixers and one crane driver. This acceleration of production so far outstripped the expectations of the nominated lift contractor that it was necessary to bring in

Progress of the structure of eleven-storey block at Trinity Road. On May 5, 1954 (left) the fourth-storey walls and columns were being erected, and on July 5, 1954 (right) the structural frame was completed. Note the cladding materials "spotted" on each floor

Eleven-storey blocks on October 7, 1954. The hanging scaffolding on Block 1 is being lowered as glazing proceeds, and on Block 2 raised as the cladding is built. The top storey of Block 3 is under construction



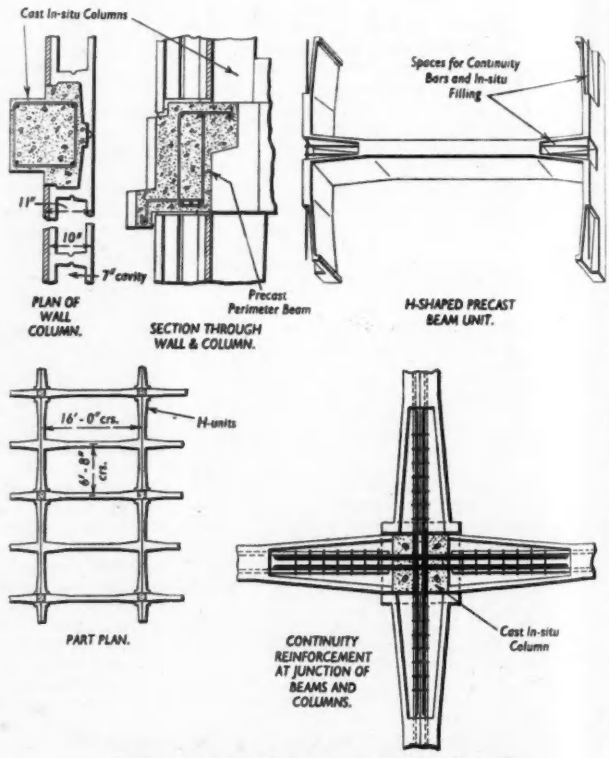
Wall panel being placed in position during construction of flour mill at Andover. The panel is of cavity construction and extends a full storey in height

another firm who was prepared to meet our requirements in point of time.

On breaking down the time expended by the crane on the construction of the frame, it was found that some time was available, so an investigation was carried out into the possibility of loading each floor with the bricks and clinker blocks required for the external wall and internal partitions. A plan showing the number required, room by room, was drawn up, the position and size of each stack agreed with the engineers and sufficient pallet boards were made available so that bricks and slabs could be unloaded from the lorry straight on to the pallet board and so save double handling. The pallet boards and bricks were lifted into position by a brick skip fitted with a quick grip and release control. This operation was carried out immediately after striking wall shutters and before placing the floor shutters in position.

Having completed the penthouse, the roof was then asphalted, followed immediately by the erection of steel outriggers mounted on the roof, from which our scaffold for the erection of the brick cladding was hung. As this was raised lift by lift, bricks from each floor were handed on to the scaffold. Mortar for the bricklayers and materials for the plasterers were supplied by a high-speed hoist, 300ft per minute, because by this time the crane had passed on to the next block. The outer skin was constructed at a rate of two and a half floors per week, i.e. four to five weeks per block. This method of scaffolding enables the bricklayer to proceed without interruption, always keeping his work at a reasonable height, and we find does eliminate the staining of the work which a standard scaffold so often gives. The bricklaying gang having raised the scaffold to the roof, the glazing and painting of the windows was carried out from the scaffold on its way down to the ground. Whilst the external skin was being erected, all trades could get to work internally under cover of the asphalted roof, and, as a result, we are able to produce finished buildings more quickly and in a planned sequence of operations whereby each block phases in with the next. Our labour strength is geared to produce six flats per week. By constructing the job vertically block by block, maximum use is made of the repetitive nature of the work (about forty of the floors repeat), and we thereby ensure that small, but highly efficient gangs of men can be quickly assembled and trained for the work. Moreover, it is a settled policy of the firm to hold together groups of men who are accustomed to work together.

I would emphasise that the completeness of the drawings at the very beginning, gave us a flying start, and the job has thus never looked back. The often inevitable change of mind just did not happen. My experience on these buildings confirms my view that reinforced concrete buildings of this kind have many advantages over steel-framed buildings, and I think I may well claim that the speed of construction of these buildings disposes of the often repeated claim that steel-framed buildings are quicker. It seems to me that these high and even higher buildings are a challenge that we gladly accept. If town planning increases the demand for them, the disparity of cost will disappear in the not too distant future.



Details of precast elements for the structure of the four-storey flour mills at Andover

Flour Mill at Andover

The repetition of a limited number of basic precast units is again evident in our second example of precast concrete work, a flour mill under construction for McDougall, Ltd., at Andover. This building is of four storeys, each floor covering about 3600 square feet, and designed for a general floor loading of 2 cwt per square foot. The completed building will be air conditioned and insulated, with attention paid in its design to the absence of dirt traps and to cleanliness generally. The structural frame has *cast-in-situ* columns and precast beams, but

in this case one of the basic precast units is a wall panel which extends to the full height of one storey. This structural system is a development of a method which has been extensively used for the construction of houses, hospitals and light industrial buildings. The contractor—Reema Construction, Ltd.—proposed use of the system, in a form suitable for a heavier building, and this suggestion was approved by the consulting engineers, Sir Alexander Gibb and Partners; it entailed an estimated construction time of sixteen working weeks, and reduction of the construction period to a minimum was of importance in this case.

The accompanying illustrations give an idea of the structural conception, and its similarity with the structure of the "Reema" house will be seen. The wall panels are 10ft 3in high and either 16ft, 13ft 4in or 8ft long; they are of cavity construction, comprising a 1½in outer skin, a 7in cavity and a 1½in inner skin, on which a 1in thickness of insulation board is cast during manufacture. The panels have stiffening ribs in the central cavity to which are attached the fitting lugs, and they are delivered to the site complete with window and door frames.

The building was designed according to the code of practice No. 114, and the concrete mixes are generally 1 : 2 : 4, though 1 : 1½ : 3 concrete has also been used. The columns are spaced on a grid of 16ft by 13ft 4in; on the ground floor they are formed with shaped heads to carry the wall and floor beams, and on other floors they are tapered, with an increased cross-sectional area at the ceiling to carry the various precast beams. All the columns are *cast-in-situ*, but the only other "wet" work of the main structure is at the joints of beams and columns, where the design has been evolved to give continuity at each joint, and hence a monolithic structure. The beams are generally widened out at their ends, and a generous space left for continuity reinforcement and an *in-situ* filling.

When a new storey is erected on the frame, the wall panels are placed in position and held by guy ropes. The internal column shuttering is erected, and the columns are cast. The way in which the wall panels act as part of the shuttering for the external columns is shown in one of the detailed sketches in the drawing facing this page. A strip of bituminous damp-proofing material is placed behind the joints between the panels. Each panel rests on a precast perimeter beam, which is also shown in the illustration; this beam holds the top of the panel below it in position, as the drawing shows, and the panel is also held at each side by the projections formed on the column.

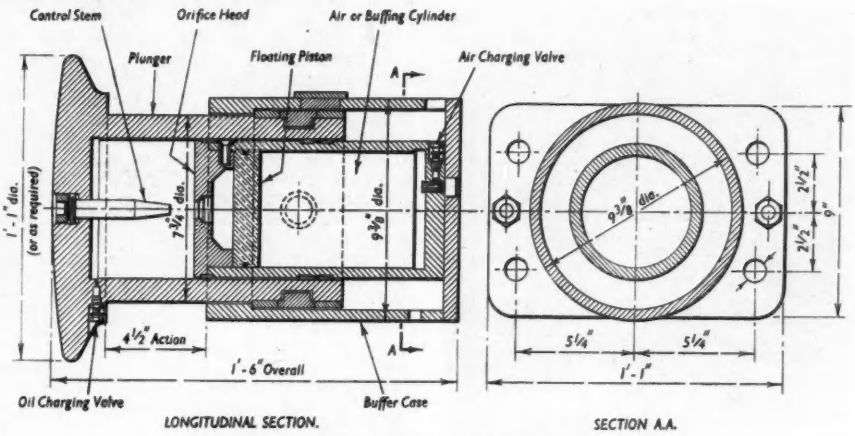
The floor beams are at 6ft 8in centres, that is with beams running over each column line (the columns are 13ft 4in apart) and at the centre of the span between columns. So as to achieve complete continuity an "H"-shaped beam unit is used; the upright legs of the "H" abut with the corresponding parts of adjacent units, so that each leg forms half of a beam spanning in the 13ft 4in direction; the cross bar of the "H" forms the beam at mid-span. This construction is clearly shown in the isometric sketch of the "H"-beam unit. This sketch shows the spaces left for continuity reinforcement and *in-situ* concrete, and clearly illustrates the way in which a beam unit of this kind gives continuity with adjacent structural elements. The "H"-shaped elements are also shown in plan in the typical beam layout. A detail of the continuity reinforcement and *in-situ* work at a column head is also shown. The beam ends are widened out (again the ends of the "H"-beam units can be seen here) and rest on the largest section of the tapered column, as shown by the dotted lines; the full lines show the column cross section for the floor above.

The "H"-shaped units have overall dimensions of 12ft by 16ft and were too large to be transported by road, and so were cast on the site. The ground floor is formed of precast panels 5ft 4in wide and spanning 16ft or 13ft 4in. The upper floors are of timber. The roof is to be of hollow precast cavity units, 5ft 9in wide and spanning 11ft or 13ft 4in; the roof is to be finished with white felspar laid on ¾in asphalt over 2in of cork. Erection was carried out with a 5-ton derrick with a 120ft jib.

Hydro-Pneumatic Buffers for Rolling Stock

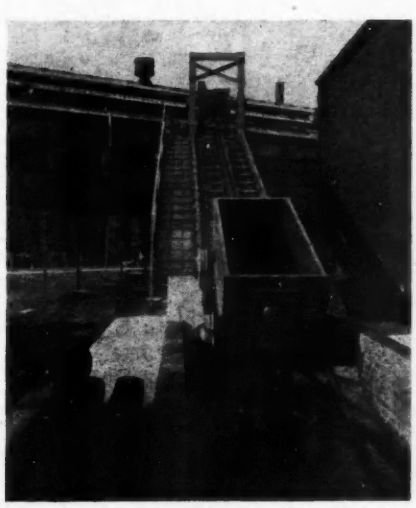
IN our issue of October 23, 1953, we described the hydraulically damped fenders of the car ferry berths at Dover. We also briefly referred to a hydraulic-pneumatic buffer, a further development in this field, designed and made by George Turton, Platts and Co., Ltd., Wincobank, Sheffield. This design of hydro-pneumatic buffer has been undergoing extensive trials in service, and we recently attended a series of tests carried out on the finalised design on a new rig at the maker's works.

The general construction of one of the new buffers can be seen in the drawing reproduced on this page. It consists essentially of a buffer case with a central buffing, or air, cylinder, and, in the chamber formed between the case and this cylinder, an annular plunger carrying the buffer head. The top of the buffing cylinder has an orifice head, the hole in which is in line with a tapered central stem projecting inwards from the buffer head. A floating piston is fitted in the buffing cylinder and the chamber formed above this piston behind the head of the buffer is filled with oil. The cylinder below the floating piston is filled with compressed air and sealed.



Arrangement of hydro-pneumatic buffer for rolling stock

In operation when a load is imparted on the buffer head by a moving vehicle the plunger starts to move back into the case, and its inward movement is retarded by the oil which must pass through the orifice head of the buffing cylinder. The resultant pressure build-up over the area of the cylinder bore becomes a retarding force to the moving vehicle. The magnitude of the retarding load is proportional to the rate of flow of oil through the orifice. As the buffing head moves back the tapered end of the control stem passes deeper into the orifice thus increasingly restricting the flow of oil. The higher the speed at which the plunger is forced inwards the greater will be the energy absorbed in discharging the oil through the diminishing orifice. As the oil flows through the orifice the floating piston is forced down the buffing cylinder and compresses the air behind it still further. After the flow of oil has ceased and the moving vehicle has been brought to rest, the load imparted by the air compressed behind the floating piston comes into effect. This pressure forces the floating piston up to drive the oil back through the orifice into the oil chamber and return the buffer to the extended position.



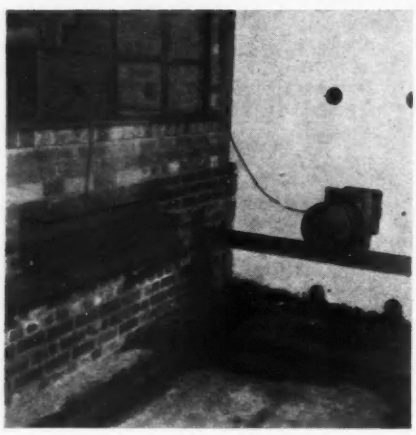
Bogie fitted with hydro-pneumatic buffer on incline of test rig

The orifice head is secured to the buffing cylinder by hollow rivets, and the bores of these rivets provide an oil passage between the hydraulic side of the buffing cylinder and the annular chamber formed by the clearance between that cylinder and the bore of the plunger. This communication with the annular chamber ensures that the pressure head across the toroidal seal of the floating piston is not materially greater than the air pressure in the buffing cylinder, thus the seal is not subjected to the high pressure generated in the hydraulic cylinder. Three automatically lubricated plastic supporting rings for the plunger are fitted on the buffing cylinder, and the plunger is guided and supported in the casing by a deep annular sleeve held in position by spigoted plugs.

The buffer conforms to the dimensions of the standard R.C.H. hollow plunger buffer, whilst it has the usual clearance between the case and plunger and is free to telescope when buffing on curves. The makers point out that buffers of this design have been in use now for three years without replenishment of either air or oil. The toroidal seal which is located in a groove in the floating piston operating in the central buffing cylinder is rendered positive in the retention of air at varying high pressures by the fact that it is pressure balanced. Following the pressure drop across the orifice the pressure of the displaced oil in front of the floating piston is only equal to that of the air pressure behind the piston; therefore it will be appreciated that the toroidal seal is maintained in close contact with the cylinder bore by oil on one side and air on the other at an equal pressure depending upon the compression of the air. However, in the event of a drop of initial air pressure after several years' service, the drop would be indicated by failure of the plunger to return to the full length after buffing, and it can be restored with a manually operated motor tyre pump as the required pressure is only in the region of 60 lb per square inch. Loss of oil is

indicated by the fact that the buffer head can be rotated easily by hand and the volume of oil can be restored by a few strokes with an oil gun. The oil and air valves are housed in recesses and a special spanner is required to reach them.

For testing buffers the firm has built the rig to be seen in the photographs we reproduce. It consists of a length of rail track set on a structural steel framework inclined at an angle of 20 deg. At its foot the track levels out in a pit and extends to a stop block consisting of a mass of concrete weighing some 240 tons. A testing bogie carried by the track has a heavy steel plate box body. It has a net weight of 7¼ tons and runs freely on roller-bearing wheels. By means of a winch at the top of the track structure the bogie is hauled up the incline to any required point. A channel in the centre of the track is drilled at intervals for locking pins used to hold a trip catch in place. This trip catch is designed



Stop block of test rig with hydro-pneumatic buffer

to lock on the front axle of the bogie and it is positioned in accordance with the speed required of the bogie when it reaches the bottom of the incline. The trip is operated by an electric switch from the control room at the side of the pit, and when its catch releases the axle the bogie gravitates down the track into the stop block. The incline is arranged for speeds up to 20 m.p.h.

Electronic equipment installed in the control cabin is designed to record the bogie speed in miles per hour, the buffer stroke in inches, the reaction in tons at intervals of stroke and the maximum, and the energy absorbed in inch-tons.

For the tests we witnessed the bogie was loaded to give a gross weight of 13 tons moving mass, simulating a loaded railway wagon of 26 tons gross. First two 4½in stroke hydro-pneumatic buffers were tested, one being mounted on the bogie and the other on the stop block ; for the second test the bogie buffer was replaced by a rubber spring buffer ; and for the third, a comparative test, both the bogie and the stop block were fitted with rubber spring buffers, each of 4½in stroke. The hydro-pneumatic buffers were charged with air at 60 lb per square inch. The results are summarised in the table.

Buffer Test Results—Gross Weight of Bogie 13 *Tons*

Run No.	M.p.h.	Reactive load, tons	Energy absorbed, inch tons	2 × 4½in available stroke / Effective stroke, in.	Buffers
1	3·54	12·2	65·2	8	2 H-P.
2	5·86	27·4	179	8+	Do.
3	7·9	51·2	325	8¼	Do.
4	10	81	520	8¼	Do.
5	11·64	114	705	8¼	Do.
6	13·66	134	970	8¼	Do.
7	14·2	159	1040	8¼	Do.
8	3·62	31·9	68	8⅛	1 rubber, 1 H-P.
9	5·77	87·7	174	8⅛	Do.
10	7	121	257	8⅛	Do.
11	2·6	30·7	35	9	2 rubber
12	3·44	198	61·5	9	—

The hydro-pneumatic buffers had an extremely low recoil energy—only 6in-tons—irrespective of the impact energy. The table also shows the low maximum reaction load of the new buffers even at high speeds, when compared with the spring buffers.

Naval Oil Tanker "Sechura"

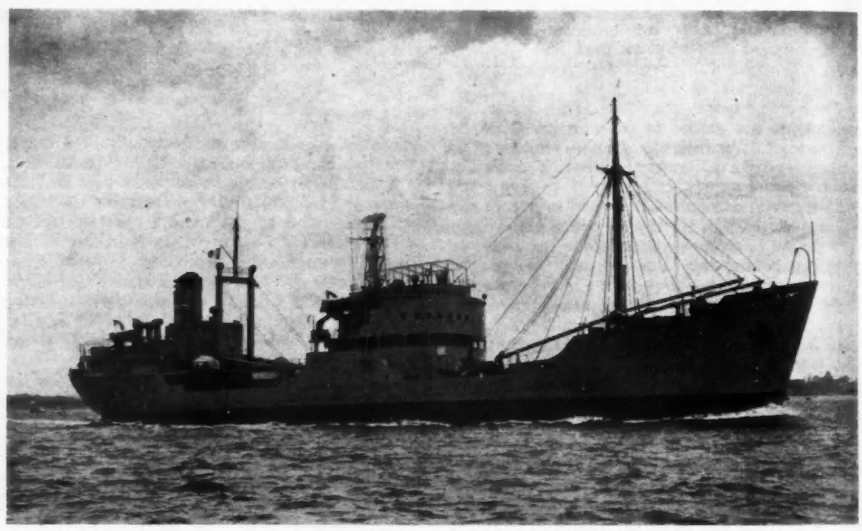
AT a ceremony held on Tuesday, February 15th and attended by the Peruvian Ambassador and officials of the Embassy, the Buque Armada Peruana "Sechura" was handed over, at the Southampton yard of her builders, John I. Thornycroft and Co., Ltd., to the Peruvian Navy. The ship, which can be seen in our illustration, has a displacement of 8700 tons and carries a deadweight of 6000 tons on the following dimensions : length overall 385ft, length between perpendiculars 360ft, breadth moulded 52ft, depth moulded 26ft and a draught of 21ft 3in. Before finally determining the ship form models were tank tested. On trials with the ship ballasted to a draught corresponding to a displacement of 8500 tons, a speed of 13·22 knots was attained to give an Admiralty constant on a s.h.p. basis of 404.

The design of the ship conforms with the usual arrangement adopted for oil tankers, the engine-room being aft, with the crew's quarters in the poop and the officers accommodated in a deckhouse amidships. The ship has been built to the classification of Lloyd's Register and not only conforms with the international conventions for safety of life at sea, but also complies with the regulations of the United States Coastguard. Decks are mainly welded, as are also the butts of the shell plating, of which the seams are riveted. Transverse framing has been adopted in wing tanks and is riveted to the shell. The tank space is divided into six triple main cargo oil compartments by two longitudinal corrugated bulkheads and corrugated transverse bulkheads. Four small wing tanks are arranged, two to port and two to starboard, abreast the main pump room, which is forward of the engine-room and separated from it by oil tanks allocated for diesel oil fuel and boiler oil. Additional oil fuel can be carried in a deep tank arranged right forward under the dry cargo hold. Double bottom tanks in the machinery space carry lubricating oil and fresh water and there are also fresh water tanks on the main deck forward of the steering gear compartment and below it.

In the main pump room there are two horizontal Duplex cargo oil pumps of 300 tons per hour at 150 lb per square inch, manufactured by J. H. Carruthers and Co., Ltd., two Weir special products pumps (40 tons per hour at 40 lb per square inch) and a Weir bilge and cargo water drainage pump capable of delivering 60 tons per hour against a 60ft head. Ventilation of the pump room is by a 12½in exhaust fan of 2000 cubic feet per minute capacity. G. and J. Weir, Ltd., has also supplied the 40 tons per hour oil fuel transfer pump and the 100 tons per hour bilge and ballast pump fitted in the forward pump room which is arranged to port in the dry cargo hold.

The cargo pumping system provides the maximum degree of flexibility in handling mixed cargoes and the tank venting arrangements prevent gas passing from one tank into any other. A steam smothering system has been installed for extinguishing fires in the cargo tanks and pump rooms and for the machinery spaces there is a total flooding CO_2 system which can be controlled from aft and amidships. Tanks are cleaned on the Butterworth system, for which the heater is fitted in the engine-room.

Steam deck machinery is installed, mainly supplied by Clarke, Chapman and Co., Ltd., and includes two 5-ton capstans having underdeck machinery on the poop ; one 5-ton capstan in the forward well on the main deck ; two 4-ton winches, together with two 8-ton constant tension winches on the poop deck extension at the mainmast ; two 5-ton winches at the foremast, and a windlass equipped with roller bow stoppers. Two 7-ton derricks, operating on the Union system, are carried on the foreside of the foremast to serve the dry cargo hold, which has a MacGregor steel hatch cover at the forecastle deck. On the aft side of the foremast is a 12-ton derrick for handling deck cargo, while a derrick at each kingpost, forward of the poop, form part of the equipment for carrying out refuelling operations at sea. John Hastie and Co., Ltd., supplied the two-ram electric hydraulic steering gear and J. and E. Hall, Ltd., manufactured the direct-expansion refrigeration machinery which uses Arcton 6 gas as a refrigerant.



The 6000-ton deadweight oil tanker "Sechura" for the Peruvian Navy

The captain has a suite on the navigating bridge and similar accommodation is provided for the chief engineer on the upper bridge deck, where are also single-berth cabins for the deck officers. Single-berth cabins for the engineer officers are provided on the bridge deck, where a comfortably furnished combined dining room and lounge occupy the full width of the deckhouse. Sixteen petty officers are accommodated in two and four-berth cabins on the port side of the house on the poop, where they have also their mess and pantry. On the starboard side of the deckhouse is the crew's mess and aft, on the same side, is the galley which is fitted with electrical equipment supplied by Henry Wilson and Co., Ltd. The crew, numbering thirty, have quarters arranged on the main deck and also on this deck is a laundry in which is fitted an electric washing machine, a hydro extractor, a drying tumbler and a steam press. A smoke room for the crew is arranged in a small separate deckhouse located immediately forward of the Thornycroft funnel at casing level. The whole of the accommodation has a mechanical supply and exhaust ventilation system fitted by the Winsor Engineering Company, Ltd. There are four 24ft aluminium alloy lifeboats, carried under

Taylor davits, and the ship is fitted with modern aids to navigation, including a Sperry gyro compass, echo sounder, radar, direction finder, and also sound reproduction and order equipment. Mounted on the boat deck aft is a 3in gun for which the ammunition is stowed in a magazine below the main deck.

Main Machinery

The ship is driven by a four-bladed propeller having a diameter of 14ft 3in and a mean pitch of 11ft and is powered by a single-acting, two stroke, Burmeister and Wain crosshead diesel engine, having five cylinders of 620mm diameter by 1150mm stroke, which develops 2400 b.h.p. at 120 r.p.m. Aft of the engine and driven by chains from the propeller shaft is a pumping unit which serves the bilge, fresh water, salt water and lubricating oil systems. For handling spare gear and engine parts there is a Vaughan hoist capable of lifting 6 tons at 5ft per minute. G. and J. Weir, Ltd., has supplied most of the pumps in the engine-room, including a ballast and standby salt water pump of 200 tons per hour capacity at a 60ft head, a 40 tons per hour bilge and general service pump, a fresh water cooling pump of 110 tons per hour capacity, a lubricating oil pump of similar size and also a fire, bilge and Butterworth system pump having a capacity of 50 tons per hour at 200 lb per square inch. The same company has manufactured the two 2200/2700 gallons per hour at 180 lb per square inch boiler feed pumps and the two oil fuel transfer pumps which can deliver 25 tons per hour against a head of 60ft. There are three 5½ tons per hour Megator fresh water and sanitary pumps and a distiller circulating pump of 3000 gallons per hour for service with the Caird and Rayner evaporator and distiller, which has a capacity of 10 tons of water per twenty-four hours. De Laval centrifugal purifiers, complete with steam heater and pump, are provided, one for diesel oil and one for lubricating oil. Starting air is supplied by two steam-driven Reavell compressors capable of delivering 88 cubic feet of free air per minute at 355 lb per square inch.

At the forward end of the engine-room is the electrical generating plant which consists of a 50kW generator driven by a six cylinder Gardner diesel engine of 81 b.h.p. at 800 r.p.m., a 12kW generator driven by a Gardner diesel engine of 24 b.h.p. at 1000 r.p.m., and a 50kW generator driven by an Allen steam engine developing 75 b.h.p. at 550 r.p.m. Also in the engine-room is a condenser, of 21,000 lb per hour capacity, with which is associated a steam-driven circulating pump capable of delivering 2000 gallons per minute against a 30ft head, manufactured by Buckley and Taylor, Ltd., and a Weir's air pump. The machinery space is ventilated by two supply and two exhaust fans, each of 10,500 cubic feet per minute capacity, provided by Woods of Colchester, Ltd., and this firm has also provided two fans of the same capacity for the ventilation of the boiler-room. In this room there are two single-ended, two furnace, oil-burning Scotch boilers, constructed by the shipbuilders, mounted on the main deck and fitted with two Howden steam-driven, forced draught fans capable of delivering 4000 cubic feet per minute. The boilers each have a heating surface of 1750 square feet and a working pressure of 180 lb per square inch and are fitted with Thornycroft oil burners designed for a maximum oil pressure of 350 lb per square inch. A Thornycroft duplex oil fuel heating unit, with a capacity of 2 × 2500 lb per hour at 250 deg. Fah., is fitted, complete with two Weir pressure pumps capable of delivering 2500 lb of oil per hour at 325 lb per square inch. For lighting up there is a Hamworthy oil fuel pump rated at 300 lb per hour.

Old Gaiety Theatre Site.—The English Electric Company, Ltd., announces that the winner of the architectural competition for the design of a new office building on the site of the old Gaiety Theatre is Sir John Burnet, Tait and Partners (Mr. Gordon T. Tait, F.R.I.B.A.). The competition was held under the rules of the Royal Institute of British Architects, and the assessors were Sir Percy Thomas, Past President of the Royal Institute of British Architects, M.T.P.I., and Mr. John Murray Easton, F.R.I.B.A.

Electronic Digital Computers

No. III—(*Concluded from page 267, February 25th*)

In this country electronic digital computers are nearing a stage in their development at which they may be applied generally in industry and commerce, for various processes involving very rapid computations or analysis of statistical data. Because of their high cost these computers have, in practice, hitherto been available only to very large organisations. In this series of articles we refer, briefly, to the activities in this field, of some British firms. This article deals with the "Mark 1" and "Pegasus" computers, developed from the Manchester University Electronic Computer and made by Ferranti, Ltd.*

ELECTRONIC digital computers being made by Ferranti, Ltd., Moston, have been evolved from the Manchester Universal Electronic Computer which was installed in the University of Manchester in 1951.* It will be recalled that this computer was developed and engineered by Ferranti, Ltd., the design being based on an experimental machine built by Professor Williams, Dr. Kilburn, and their associates in the electrical engineering department of the University.

The Manchester machine, like other digital computers, is designed to deal with numbers represented as a sequence of digits. With them it can perform three kinds of functions. First, it can carry out all the operations of arithmetic very rapidly. Secondly, it can store or remember a great many numbers; it can, for example, store in its "memory" (a magnetic disc) more than 15,000 twelve-digit decimal numbers and can recall any one of them in about 33 milliseconds; it can also store 256 twelve-digit numbers in a temporary (electrostatic) store from which the numbers are immediately accessible as and when required for any calculation. Thirdly, the computer has the ability to decide, at any stage of the calculation, which of two or more contingencies has occurred and to decide its subsequent course of action accordingly, in the light of prescribed instructions previously fed into the machine.

These instructions are fed into the machine in coded form: in the case of the Manchester computer this is done on punched teleprinter tape which is scanned or read by photocells in the computer itself. All the operations in the computer are carried out in the binary system of digits, the numeral "1" being represented by a single electrical pulse and the numeral "0" being represented by the absence of a pulse. Each number and each instruction stored and operated on in the computer, therefore, consists of a distinctive pattern or series of unidirectional pulses. The results of the computation can be given on punched tape or typed out by teleprinter.

Various programmes have been devised for checking the operation of the machine and they can be used by the maintenance engineer in the diagnosis of faults and in the location of faulty components.

The computer has been described elsewhere†;

* The Engineer, July 13–27 1951.

† *Loc. cit.*

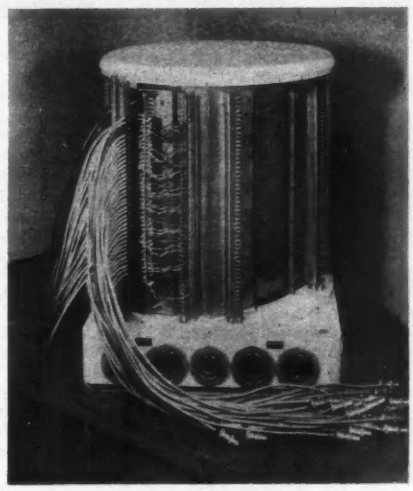


Fig. 11—Rotating magnetic drum which constitutes the main store of the computer

Fig. 10—Mark 1* Computer developed from the Manchester University Electronic Computer and manufactured for the Ministry of Supply

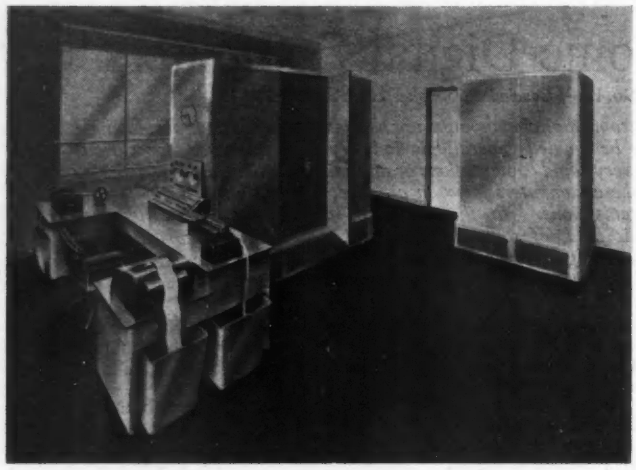


Fig. 12—"Pegasus" packaged computer. One of the standardised plug-in units can be seen partly withdrawn from its rack in the main computer cubicle. The power supply cabinet is on the right.

here it will suffice to recapitulate some of the main particulars of the equipment. It operates serially, the basic pulse repetition frequency being 100kc/s. It handles numbers of twenty or forty binary digits (six or twelve decimal digits). The equipment is housed in two bays, each 16ft long, 8ft high and 4ft wide, and the operator sits at a control desk. A more compact commercial version, developed in 1951 from the Manchester computer, is illustrated in Fig. 10.

A distinctive characteristic of the Manchester computer is the use of cathode-ray tubes as a means of storing numbers at high speed; 10,000 binary digits can be stored in this way. The main store, consisting of a rotating magnetic drum (Fig. 11), has a storage capacity of 650,000 binary digits which is equivalent to about 15,000 twelve-digit decimal numbers.

The performance times for typical routines and sub-routines are specified in the following table.

Operation	Time, milliseconds
Multiplication times	2·2
Addition time	1·2
Square roots and reciprocal square roots	105
Cosines of angles to 11 decimal digits	80
Reciprocals	95
Inversion of matrix of order $n \times n$	$0 \cdot 04n^3$

To dissipate the heat represented by a power consumption of 27kW the cubicles containing the electronic equipment are continuously ventilated by means of a closed-circuit air system with a heat exchanger connected to an external cooling unit. The main electronic components include about 4000 valves, 2500 capacitors and 15,000 resistors.

Practical applications of the Manchester computer have been described elsewhere.‡ A typical example of the use of the computer is described in an article, "Electronic Calculation of Critical Whirling Speeds," beginning on page 294 of this issue.

A recent development is that of the Ferranti Packaged Computer No. 1, otherwise known as "Pegasus," an electronic digital computer manufactured under licence from the National Research Development Corporation. "Pegasus" is a medium-sized general-purpose equipment designed to carry out the computational work that arises in many forms in industry, research and commerce. It is a packaged computer (Fig. 12) built up from a range of standardised plug-in packages—a construction which facilitates maintenance by the replacement of the faulty package, repairs to the package itself being carried out later without causing the computer to be taken out of service.

Particular attention has been paid to ease of programming, and a comprehensive range of "orders" has been developed to define the operations to be carried out on the numbers stored in the machine. A modified single address code is used and the difficulties of optimum programming do not arise.

All the actual computations are done in a bank of registers or stores. Each store is a nickel delay-line holding one "word" (consisting of a number or two instructions), represented by a series of pulses. These pulses are amplified and recirculated in the nickel delay-line so that the number is held continuously until it is required for computation, when it is immediately available. Seven of the delay lines are available for all arithmetical, logical and modifying operations and each line is equivalent to the usual single "accumulator" in combination with a "B-line." Addition and subtraction facilities are also provided by thirty-two registers. There are separate registers for the input and output of information.

The main store of the computer is a magnetic drum rotating at 3750 r.p.m. and containing 4608 "words." Information, consisting of both orders and data, can be transferred, as required, for the computation, to and fro between the drum and the computing store in blocks of eight "words" or in single "words."

Provision is made for input and output to be by punched paper tape and for using the equipment with an automatic typewriter. Provision is also made for the use of other forms of inputs and outputs (including a high-speed line-at-a-time printer, punched cards and magnetic tape) as they are developed. By means of a high-speed switching system any one of a number of available input and output equipments can be selected automatically.

Various monitoring facilities are provided: for example, it is possible to examine any register in the computing store and to stop at any specified order. The computer can also be set up to obey orders one at a time. In association with each number held on the magnetic drum there is a check digit which is scanned by the machine every time a transfer is made to the computing store; accordingly, any error in the transfer will be detected, an indication of this will be given on the machine and the calculation will be stopped. A marginal testing facility can be applied by varying the high tension voltages while the machine is running, with the object of detecting a faulty component before it would fail in normal running. A test programme is available to help in locating the faulty component.

The "word" length in "Pegasus" is thirty-nine binary digits (one of which is a sign digit), being equivalent to eleven decimal digits. One word alternatively carries two orders. The digit time is 3 microseconds.

Using punched paper tape, the maximum input speed is 200 characters per second, while the output speed is fifteen characters per second. Alternatively the output can be typed at a maximum speed of 6·7 characters per second. Most orders can be completed in 0·3 milliseconds; multiplication takes 2 milliseconds and division 5 milliseconds.

The complete equipment is illustrated in Fig. 12. The computer proper consists of racks of plug-in packages housed in a cubicle measuring 93in by 25in by 84in. On the right is the power supply cubicle which measures 65in by 25in by 84in. All the operational facilities are grouped in a control desk which measures 54in by 87in.

Manufacturing Agreement

An agreement has been made between Ferranti, Ltd., and Powers-Samas Accounting Machines, Ltd., whereby these two companies will collaborate in the design and manufacture of computing equipment, and meetings have been held recently in Manchester and London to exchange ideas and techniques.

We may recall that Powers-Samas Accounting Machines, Ltd., has been manufacturing punched card equipment in England for forty years. Originally this equipment was mechanical but in recent years electronic principles have been applied in the design of the company's medium and large card equipments. As a result an electronic punched card calculating machine (known as "EMP" or Electronic Multiplying Punch) has been put into production.

‡ The Engineer, July 10, 1953.

Nuclear Power Programme*

Probable Lines of Development of Nuclear Power

THE Calder Hall station is the first attempt in the United Kingdom to produce electricity from nuclear energy on a large scale. Future developments, so far as they can now be foreseen, are likely to be directed at two main objectives: using the main nuclear material, uranium, more efficiently; and reducing the capital cost per kilowatt of a nuclear power station, in terms both of the construction of the reactor and of its initial charge. During the next ten years two types of reactor are likely to be brought into use on a commercial scale. The first type will be similar to those now being constructed at Calder Hall, but improvements in design during the period should enable the later models to show a great advance in efficiency compared with the earlier ones. They will be gas-cooled graphite-moderated "thermal" reactors using as fuel natural uranium or slightly "enriched" uranium, i.e. fuel having a slightly higher fissile content than natural uranium. The first improved models could be designed and built so as to come into operation in about six years' time. These first reactors will burn only a very small proportion of the natural uranium placed in them, but they will produce, in addition to heat, the element plutonium, which does not occur in Nature. This plutonium, which can be extracted chemically from the used fuel, is potentially very valuable; it is a pure fissile material, whereas natural uranium contains only one part in 140 of fissile material.

The second type of reactor that may be built for commercial operation during the next ten years is a liquid-cooled "thermal" reactor. This type requires more complicated techniques, which at present would result in higher costs. But with further development liquid-cooled reactors should be able to give a much higher heat rating† than the first gas-cooled reactors for the same capital cost. They might therefore eventually prove more economic than the gas-cooled reactors, although the comparison will depend on how much the gas-cooled type can be improved. They could take any of several forms, most of which need "enriched" fuel, and could use for this purpose the plutonium produced in the earlier reactors in conjunction with natural uranium. The first commercial liquid-cooled reactors might be built during the latter part of the next ten years and begin operating about 1965.

Development after 1965 may take various forms; thorium may be used, at first in conjunction with plutonium, as an alternative fuel; "homogeneous" and "fast breeder" reactors may be developed. It has already been decided to build a full-scale experimental model of a "fast breeder" reactor capable of producing power on a site at Dounreay, in Caithness. There is no doubt that the commercial reactor that emerges after these developments as the most suitable, whatever type it may be, will have a lower capital cost per kilowatt and a better utilisation of the nuclear fuel than any of the earlier reactors.

The Probable Cost of Nuclear Power

An estimate can be made of the cost of electricity produced by the two types of reactor likely

* Excerpts from the White Paper, "A Programme of Nuclear Power." H.M. Stationery Office.

† The heat rating of a reactor is the rate of production of heat from each ton of fuel in the reactor.

to be in commercial use in the next ten years, although it must be subject to a wide margin of uncertainty. Experience of operating reactors at high temperatures and under the high rates of heat extraction required for power is still limited. To the technical uncertainties about the characteristics and performance of the reactors themselves must be added the rather different uncertainties about the supply and value of the nuclear materials required by and produced by a reactor system. In what follows the results of making assumptions on these counts should be regarded as giving only an approximate and not an exact estimate of cost.

Capital and Overhead Costs.—A reasonably accurate estimate of the constructional cost of the first commercial stations can be made. A station of the same type, but designed to produce fissile material for military purposes as well as electricity, is already being built at Calder Hall at a cost of £15,000,000 to £20,000,000. Even the first commercial reactors of the Calder Hall type can be expected to show a higher heat rating than those now under construction, so that the capital cost per kilowatt will be lower. A new station might have an electrical output of 100-150MW or even 200MW. We have no experience on which to base on estimate of the working life of a reactor in a commercial station, but a life of between ten and twenty years seems to be a reasonable technical assumption. As nuclear stations will have a higher capital cost and a lower running cost than other stations, they will be run as base-load stations at a high load factor (perhaps 80 per cent). On these assumptions a rough figure for the annual overhead cost for each unit of output can be calculated. The works and operating costs, excluding fuel costs, can be estimated from the experience of operating coal-fired power stations and the military reactors at Windscale.

Developments in reactor design, such as the introduction of liquid cooling, should gradually lead to much higher heat ratings without much increase in capital cost. This would reduce still further the capital cost per kilowatt and thus reduce the overheads.

Fuel Costs.—The fuel cost depends on three things : the cost of the raw material, uranium ; the processing cost, including the conversion of ore into fabricated fuel elements, the chemical processing of the used fuel elements and the extraction of plutonium from them; and the "level of irradiation," that is, the amount of heat that can be got from each ton of fuel in the reactor before it has to be taken out.

Her Majesty's Government consider that enough uranium will be available for the civil programme over the next ten years, after making the best assessment possible of world supplies and of world requirements for all purposes. The cost of the initial charge of fabricated uranium for one of the early types of station similar to Calder Hall may amount to about £5,000,000 ; a new charge costing the same will be needed every three to five years. The cost of processing uranium, both before and after use, is known from the processes now being worked at the Springfields and Windscale factories for the military programme. In the early stages of a power programme the processing costs will be similar, but big reductions can be expected later when new factories are built.

It is expected that it will be possible to extract as much as 3000MW-days of heat from every ton of fuel. This is the equivalent of the heat from 10,000 tons of coal. There is as yet no practical experience of this level of irradiation at high temperatures and the metallurgical behaviour of the fuel elements is uncertain. But there are many lines of development which should overcome such metallurgical defects as may appear.

The Cost of Electricity and the Credit for the Plutonium By-product.—Some credit should be allowed for the fissile by-product plutonium. It is in many ways equivalent to uranium 235, another form of fissile material. But plutonium can be extracted by chemical means from a power reactor's used fuel for only a fraction of the cost of separating uranium 235 from natural uranium in a diffusion plant. When concentrated fissile material is available in quantity there will be great scope for the design and development of more advanced and more efficient reactors that need "enriched" material and will not operate on natural uranium. For example, most types of liquid-cooled reactor need "enriched" material ; and, looking further ahead, concentrated fissile material in the form of either uranium 235 or plutonium is required for a "fast breeder" reactor or for starting a thorium system. In this manner the early reactors will be producing not only electricity but also the capital equipment (i.e. the initial charge of fissile material) for future power stations. Without the plutonium it would not be possible to build up a system of nuclear power stations of steadily advancing efficiency.

In the early stages of an expanding nuclear power programme it is to be expected that concentrated fissile material will be scarce and that if there were a free market its price would be high. It will be required for enriching the fuel charge in new commercial reactors, and also for many experimental and development purposes, including the fuelling of prototypes of advanced design. Eventually the system will reach the stage where more plutonium is produced than the new power stations require ; its "market" price will then fall and it might be used as a substitute for natural uranium rather than as concentrated fissile material. This is unlikely to happen for fifteen or twenty years.

It is not obvious what is the right value to put on the plutonium produced, although the effect on the net cost of electricity could be considerable. A high value in the early stages of the programme means a lower net running cost for the early reactors, but adds a heavier capital charge on to the later ones, which they might well be able to afford because of their higher efficiency. Limits can be set to the value of the plutonium by considering the uses to which it might be put. At worst it could be fed back into a reactor as fuel in place of natural uranium ; and since natural uranium contains only one part in 140 of fissile material, plutonium should be worth at least 140 times as much, weight for weight. At best plutonium is not likely to be worth more than the cost of uranium 235 separated from natural uranium in a diffusion plant. There is a wide range between these limits, but both values can be measured in terms of thousands of pounds sterling for a kilogramme of plutonium. In the early period it is thought right to allow for the plutonium at a rate of many thousands of pounds a kilogramme ; the value should eventually fall, but would have a significant effect on the cost of generating electricity.

On the assumptions set out above, and taking what appears to be a reasonable value for the plutonium, the cost of electricity from the first commercial nuclear stations comes to about 0·6d. a unit. This is about the same as the probable future cost of electricity generated by new coal-fired power stations. If no credit were allowed for the plutonium the cost of nuclear power would be substantially more than 0·6d. a unit. Later stations should show a great improvement in efficiency, but the value of plutonium would probably fall considerably during their lifetime. Even so their higher efficiency should enable them to remain competitive with other power stations.

These estimates assume that all the plutonium is used for civil purposes, as would be most desirable. No allowance has been made for any military credits.

Cost of Programme.—The capital expenditure on the construction and installation of the stations in the programme will be considerable. The cost of the first two stations together (comprising four reactors) would probably be between £30,000,000 and £35,000,000. The next two stations which would have a much higher output would cost perhaps slightly more, while the cost of the last eight stations would be in the region of £125 million in total. The cost of the initial charges of uranium, including fabrication, might amount to a further £40,000,000. The new ancillary plant that would be required within the ten-year period might cost £30,000,000. The concurrent capital expenditure on prototype development might be £30,000,000 to £40,000,000. The cost of the ten-year programme might therefore come to £300 million. The rate of expenditure on the commercial applications of nuclear power would rise steadily during the period and the total over the ten years would amount to more than the £300 million, since it would include expenditure on stations that would not be completed until after 1965 and do not appear in the present programme.

This investment will not be a wholly additional demand on the economy. The nuclear power stations will be built instead of other types of station. The investment by the Electricity Authorities in new coal or oil-fired generating capacity over the next ten years would, in the absence of nuclear power, probably be of the order of £1200 million. With a nuclear power programme there will be a significant reduction in this figure which can be set off against the investment in nuclear power. The National Coal Board should also be able to reduce its investment programme in some ten years' time below what would have been necessary in the absence of nuclear power.

No accurate assessment can be made so far ahead of the amount of additional investment that the economy will be able to afford. All that can be said is that, given a normal rate of growth of gross national product and given that a reasonable proportion of the increase in resources is made available for an increase in investment, there would not appear to be any great difficulty in accommodating a nuclear power programme on the scale here proposed. It is unlikely that the rate of expansion of investment in the fuel and power industries over the next ten years, even including this programme, will exceed the rate of the expansion in real terms that has taken place since 1948.

Long-Term Prospect.—From about 1965 it may be economically desirable to build nuclear power stations instead of coal-fired stations, even without taking account of any long-term difficulties in the supply of coal. Cheap power is a great asset to any industrial country and the more quickly we can convert power generation to the cheaper system the sooner we can hope for a reduction in the real costs of production.

On the provisional programme the new nuclear power stations would by 1965 be meeting a quarter of the total requirement of new generating capacity. How quickly it would be possible to expand the programme to match the whole of this requirement will depend upon the progress made in the first ten years. The programme for this first period may be subject to frequent and major change according to the speed of technical development and the success of the early stations. Any attempt to forecast the developments after 1965 must be even more uncertain

The possibilities of expansion will depend to a great extent on the speed with which the necessary techniques are mastered by industry at large. The Atomic Energy Authority will continue to make new information available and to provide training ; with this help industry should acquire wide experience in carrying out a ten-year programme of the type that has been outlined and this would make possible a much greater expansion after 1965 If all went well it might be practicable by the early 1970s to expand the rate of construction of nuclear power stations to match our total requirement of new generating capacity, which by this time might amount to about 3000MW a year On this assumption the total nuclear power station capacity installed by 1975 would be of the order of 10,000 to 15,000MW, the whole of which could be used for base-load operation. The nuclear power stations would then be producing electricity at a rate equivalent to that produced by about 40,000,000 tons of coal a year.

Another possible limitation on the rate of expansion in the later years is the supply of nuclear fuel, particularly the more highly enriched material that will be needed for some of the advanced types of reactor. By the late 1960s the early reactors should be producing plutonium in quantity and this would be available for the later reactors. The provisional programme and the further expansion thereafter will also call for increased supplies of uranium, and no doubt other countries will be increasing their commercial demands at the same time. Recent evidence suggests that uranium is more plentiful than was once thought ; considerable workable deposits of medium-grade ore are known, while the widespread existence of low-grade ores implies that adequate quantities can be produced from them if necessary. Moreover, the expansion in

the requirement of uranium should be mitigated by the greater economy in its use that will by then have been achieved and by the possible development of the substitute fuel thorium, which should be available in considerable quantities if it is required. For these reasons Her Majesty's Government are confident that the necessary supplies of raw material will be available to meet the increases in demand.

Safety.—The disposal of radioactive waste products should not present a major difficulty. The problem is primarily one for the chemical processing plants, which will be few in number, and not for the power stations. The volume of waste will be small and great efforts are being made to determine the most economical methods of storing or disposing of it. There are many valuable uses for it which may be able to absorb a great part of the output. Any material that is discharged will be tested to ensure that it is of extremely low radioactivity, so that it will be harmless and comparable in effect to the natural background radioactivity which is always present.

The Development of Reactors

There are four types of atom that can be used as moderator in a thermal reactor—carbon, light hydrogen, heavy hydrogen and beryllium. Carbon, in the form of graphite, is likely to be the most practical moderator in the immediate future. Light hydrogen in light water (ordinary water) is a possible alternative for reactors producing power on a large scale. These two have obvious advantages over the others from the supply point of view. A reactor also needs a coolant, and here, too, a range of possibilities is open comprising at present a gas such as carbon dioxide or helium, heavy water, light water and molten sodium metal. Carbon dioxide and light water are the most probable choices for this country in the next few years.

The only reactor for commercial power production that is within our present technical reach in terms of design and construction in the near future is the type now being built at Calder Hall, using graphite as the moderator and a gas, probably carbon dioxide, as the coolant. The first reactors of this type designed specifically for the commercial generation of electricity could be built beginning about 1957, and begin operating in about 1961. The heat rating would be relatively low, so that the capital cost for each unit of electricity sent out would be high.

The next step in the design of thermal reactors would be to increase the heat rating. Higher ratings should be obtainable from advances in the design of the gas-cooled reactors. Alternatively, a liquid could be substituted for a gas as the coolant, but this gives rise to more complex technological problems and, unless heavy water is used, requires a higher concentration of fissile material in the fuel than is present in natural uranium. This higher concentration could conveniently be provided by the plutonium produced in the early reactors. These enriched reactors could themselves produce plutonium 239, which could then be used for enrichment in further liquid-cooled reactors, or for starting a thorium system or a fast breeder reactor, or could be fed back into the same reactors instead of natural uranium.

A large-scale prototype of a liquid-cooled thermal reactor could probably be constructed and fully tested by about 1963. This might enable commercial reactors of the same type to be completed by about 1965, by which time plutonium would be beginning to come from the early Calder Hall type reactors. One type that could probably be produced on a commercial basis by that date is a light-water reactor, using light-water under pressure, both as coolant and moderator. Other possibilities are liquid-sodium-cooled graphite-moderated reactors and heavy-water reactors.

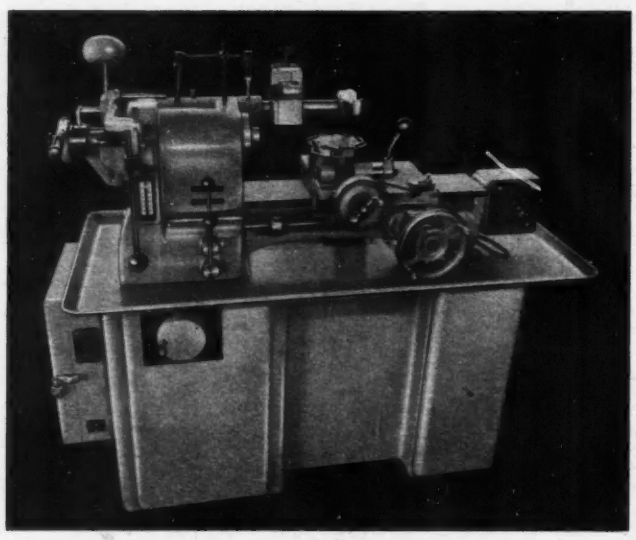
The design of a thermal reactor might be still further simplified, with a saving in capital cost, if its fissile material were supplied in the form, not of solid metal rods, but of some kind of solution or suspension which could also serve as coolant and moderator. A homogeneous reactor, as this type is called, should also have lower operating costs, since there would no longer be any need to fabricate solid fuel elements and encase them in protective material to prevent chemical and corrosive attack by the coolant. It might have a small positive gain factor. It is unlikely that a prototype of a commercial station could be constructed until at least the mid-1960s.

In order to obtain breeding of plutonium with a large positive gain factor, a fast reactor will be required, i.e. a reactor without a moderator in which the neutrons are permitted to cause fission of the fuel while they still have a considerable fraction of the energy with which they are born. The small core of a fast reactor presents many difficult technical problems, associated both with heat transfer and with the effect of high temperature on the fuel elements. The solution of these problems will take time. The design of an experimental model of a fast reactor capable of producing power is already in hand. This will be built at Dounreay and will produce data and experience for further developments. A prototype of a commercial station is not, however, likely to be tested until 1965 at the earliest, and production plants could not be expected to be in operation until the 1970s.

Chucking Turret Lathe

A CHUCKING turret lathe made by Hardinge Machine Tools, Ltd., Hanworth, Feltham, Middlesex, which is illustrated below, is fitted with an eight-station turret and is particularly intended for precision production work. The turret is mounted on the carriage cross slide and has both longitudinal and transverse movement. Chucks up to 6in capacity can be fitted on the spindle, which is bored $1^{5}/_{32}$in and also takes collets for up to 1in diameter bar. The maximum distance between the spindle nose and the turret face is 13in.

The bed of the machine, unlike that of the conventional lathe, consists of a single hardened and ground steel plate, without any centre slots or openings. The precision finished sides of this bed form dovetailed ways on which the carriage slides and is aligned with the headstock. The spindle is driven through a variable-speed gear by a two-speed motor rated at 1 h.p. at 1500 r.p.m. and ½ h.p. at 500 r.p.m. Through this drive a stepless range of spindle speeds from 125 to 3000 r.p.m. is available.



Lathe with eight-station turret mounted on carriage cross slide and fitted with threading attachment. Stepless spindle speeds from 125 to 3000 r.p.m., and stepless feeds from ¼in to 7in per minute are available on this machine

The eight-station turret built into the carriage cross slide has a top plate of hardened and ground steel with two slots machined in it for the tool holders. Four of the tool holders supplied with the machine are each designed to take two tools, and the remaining four holders each take one tool. At each of its stations the turret is located and locked by a hand lever operated yoke piece which registers on a buttress in the side of the turret. The faces of this yoke locate on the domed ends of adjusting screws in the buttresses, and through these screws the setting of any turret station can be adjusted with precision without affecting the position of the remainder of the tools.

A tee slot is milled in the top of the carriage at the side of the turret cross slide to take a stop drum. The four bars of this stop drum can be set to limit the movement of the cross slide for any four of the turret stations.

A ¼ h.p. variable-speed motor built into the carriage provides the drive for both the longitudinal and transverse feeds which range from ¼in to 7in per minute.

A threading attachment for the machine enables the cutting of internal and external threads up to 6in diameter. With this attachment a cylindrical lead screw of the required pitch is fitted on a ground extension of the spindle at the rear of the headstock. A follower with a matching thread is fitted on the follower arm, which is operated by a hand lever. This arm is connected to the threading tool head by a bar which moves through long adjustable bearings at the rear of the headstock. When the follower arm is lowered to register the follower on the lead screw it draws the guide bar, and through it the threading head, along the workpiece. At a predetermined point a thread length control piece comes into effect to release the follower from the lead screw and the tool from the work.

"Hot Spray" Process for Anti-Corrosive Compounds

MANY difficulties affect the successful spraying of semi-solid anti-corrosive compounds. Excessive quantities of thinners are often required and their subsequent evaporation may result in an inadequate coating as well as contaminating the atmosphere with solvent vapours. The normal method of applying the compound with a brush is wasteful of both time and material and gives an uneven finish and also results in insufficient coverage in inaccessible places. Experiments carried out using Caltex Rustproof Compound L, a product of the Regent Oil Company, Ltd., in conjunction with the Atlas Diesel KV.3 Cup Heater and an Ecco 306 spray gun have resulted in the development of a "hot spray" process.

The compound, which has a melting point of 120 deg. to 125 deg. Fah. and contains 12 per cent volatile thinner, is a semi-solid and a blend of mineral oils and petroleum jelly containing special additives which give it non-drying, flexible and adhesive qualities. It provides, it is claimed, a protective coating which does not harden or crack and will withstand rough treatment and both tropical and Arctic temperatures, none of these qualities being affected by the use of the "hot spray" method. In this method the temperature of the compound is raised to 140 deg. to 160 deg. Fah. in the cup heater. It is then sprayed at a pressure of 45 lb per square inch by the gun, which has special internal mixing arrangements and which gives the required atomisation. On contact with the surface being sprayed the globules immediately congeal, thus eliminating wasteful backspray and resulting in an even coating. The compound can be sprayed on to a surface that is not completely moisture-free since the coating absorbs any moisture and then expels it to the surface, where it is lost through evaporation.

Extension to a Welding Research Department

DURING a recent visit we had the opportunity of seeing the newly completed extension to the research department of Murex Welding Processes, Ltd., Waltham Cross, Herts. This section is concerned with electrode development and quality control of production electrodes, the suitability of established electrodes for unusual applications, and the investigation of problems raised by customers.

The main bay is equipped for welding with alternating current or direct current of up to 1500A, by semi-automatic and automatic machines. Weld specimens can be tested on a hot crack testing machine in which the weld is subjected to bending at a constant rate while welding is in progress. For the use of individual welders, seventeen cubicles have been constructed. Our first illustration shows the interior of one of these which has been laid out so as to obtain the maximum of working efficiency as well as of comfort. The walls consist of asbestos-lined, 1½in thick fireproof panels set in frames made from extruded aluminium sections. The control panel comprises 8in "Cirscale" a.c. and d.c. ammeters and voltmeters, process timers, isolating switches, terminals and indicator lights. Alternating current is supplied by a Murex welding transformer and current regulator, while direct current is supplied by a motor generator set. These sets are housed in a separate room so as to reduce the noise inside the laboratory, and each is remotely controlled from the cubicle which it serves. In addition to the usual extraction facilities, hot or cold ventilating air is provided and can be directed by the welder to where he requires it.

Apart from the section described, the building houses the electrode development laboratory, materials testing and research laboratories, and the Murex Welding School, where operators from outside the firm are trained. The school includes a small lecture theatre and a demonstration room, where welding arcs can be studied by projecting them on a screen.

In the electrode development laboratory, equipment is set up for the extrusion coating of small batches of wires with either standard or experimental flux mixtures. The batches are then dried under simulated factory conditions. Full stocks of minerals and chemicals are carried for producing the mixes; ball mills and sieving machinery are housed in a separate room in order to avoid dust and noise inside the laboratory. The testing department is equipped with a 50-ton Avery testing machine, Wöhler fatigue testing machine, and Izod and Charpy impact testers.

Bending tests of specimen welds and short-time creep tests, can also be conducted. In the metal stores, stocks are kept of some thirty alloys, each in several sections and thicknesses in addition to a large stock of steel plate. Test specimens for development and quality control are needed in large quantities and a substantially equipped machine shop exists for their production.

Extensive facilities are provided for routine chemical and spectrographic analyses. Metallurgical investigations include both radiographic and crystallographic X-ray work. Much research is carried out on the subject of gas absorption, for which the apparatus shown in our second illustration was built, while the development of electronic devices for the measurement of arc characteristics is being undertaken by the process research section.

An instrument workshop is available for the construction and repair of apparatus, and there is a reference library which serves the whole of the department.

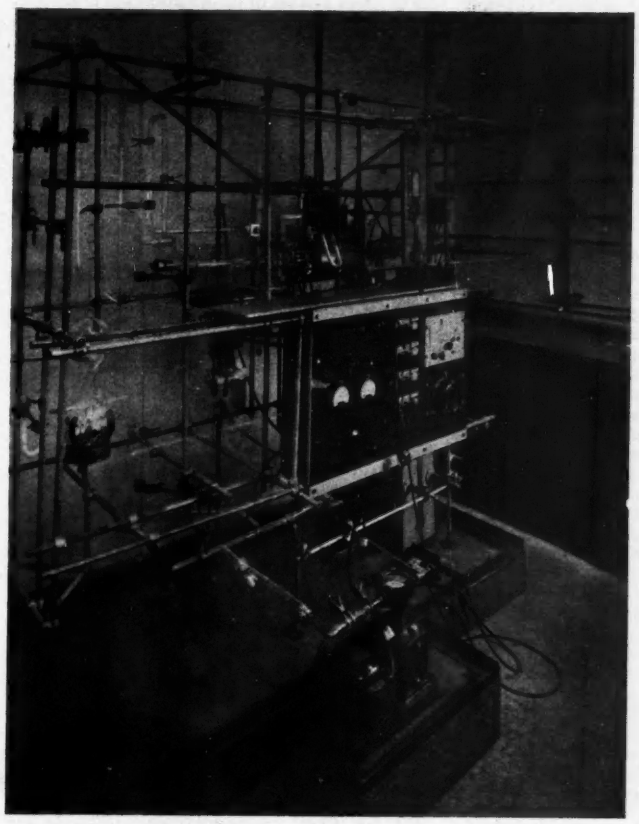


Fig. 2—This gas analysis apparatus is equipped with an air lock for introducing the weld specimen into the vacuum furnace (above the instrument panel)

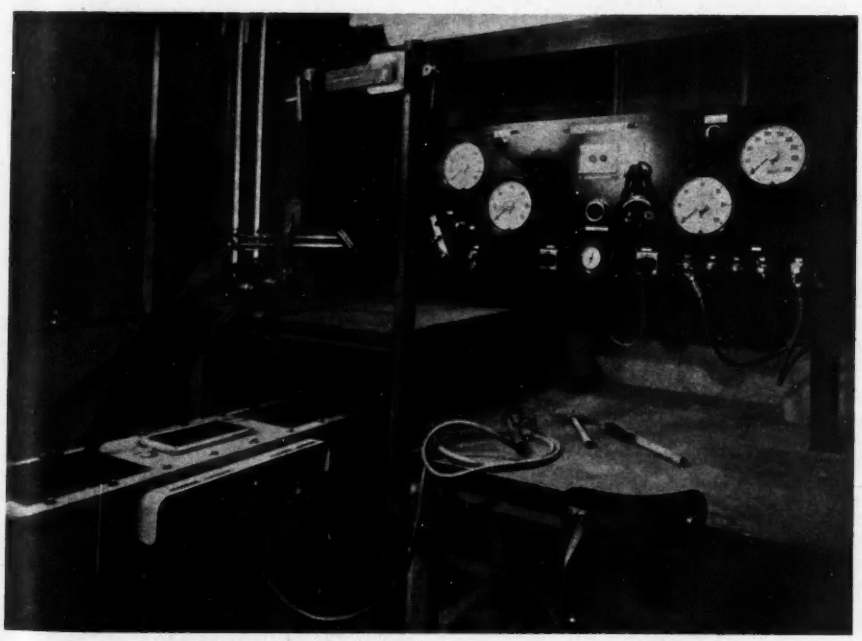


Fig. 1—Close-up of the control panel and welding bench in one of the welding booths in the research welding section

Research Building

The research department is housed in a single-storey building of steel-frame construction having external cavity walls faced with Uxbridge flint bricks. The roofing is carried out partly in steel and partly in precast concrete slabs and hollow pots, all roof portions being insulated with cork and weatherproofed with asphalt. On the basis of experiments, the rooms where welding is carried out are painted with Myosotis blue, which has about one-tenth the reflectivity of white paint. This colour accordingly predominates, with pipe work painted in the appropriate British standard colours.

Steel Supplies

A REFERENCE to steel demand and production has been made this week by Mr. R. F. Summers, chairman of John Summers and Son, Ltd., in a statement accompanying the firm's annual report. He says that it must be remembered that in a basic industry such as steel the raising of production by a substantial amount entails the expenditure of vast sums of money, and the lapse of several years before the plan can be put into operation. Much has been said, the statement goes on, as to what should be the output of steel in this country, and widely varying totals have been mentioned, but, Mr. Summers urges, the great progress in production that has been made since the war should not be overlooked. In 1946, steel output was 12,700,000 tons; in 1954 it was 18,520,000 tons, and with the present plans in contemplation it is expected that by 1958 steel production may reach 22,000,000 tons. Mr. Summers adds in his statement that the whole question of the shortage of steel sheets is being earnestly considered by the industry. An endeavour is being made, the statement says, to forecast on a realistic basis the likely requirements of steel sheet over the next few years.

Metallurgical Topics

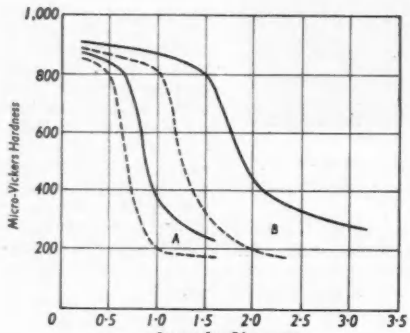
Effect of Alternating Stresses on Diffusion and Precipitation Processes

It may be recalled that G. Mahoux,[1] as long ago as 1930, observed an improvement in the diffusion of nitrogen in the nitriding process when the specimen was subjected to high-frequency oscillations, and O. Meyer, W. Eilender and W. Schmidt,[2] in their investigation of the nitriding process, found that in general diffusion of nitrogen was accelerated by heating the steel in the field of a high-frequency alternating current.

The subject of the effect of alternating stresses on diffusion and precipitation processes has been taken up by H. Schenck and E. Schmidtmann.[3] All their experiments were carried out on a basic Bessemer rimming steel containing carbon 0·06, manganese 0·29, sulphur 0·025, phosphorus 0·051 and nitrogen 0·018 per cent.

Cementation Under Pulsating Stress

For the study of cementation, a tensile specimen of 12mm diameter, 50mm gauge length, bored with a hole 3mm diameter for a thermo-couple, was used. The experiment was carried out in an equipment fitted to a 100-ton universal testing machine with a 50-ton pulsator attached. The specimen was screwed to the lower shackle of the testing machine and enclosed in a protective container. The space between the specimen and the wall of the container was packed with the carburising mixture, which consisted of 60 per cent of fine charcoal and 40 per cent of barium carbonate. The whole was surrounded by an electric furnace, capable of raising the temperature to 900 deg. or 950 deg. Cent. Owing to the low strength of steel at 900 deg. Cent. it was not possible to give it elastic alternations, and if the deformation was not regulated the test piece received only a succession of jerks. In order to

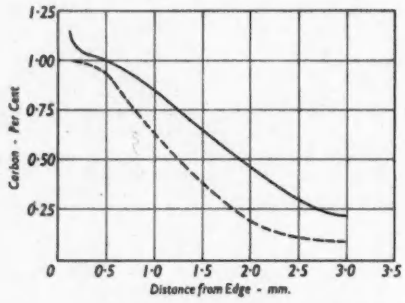


– – – – – – Unstressed. ——— Under pulsating stress. *A*—Carburised 4½ hours at 900 deg. Cent. *B*—9½ hours at 950 deg.

Fig. 1—Effect of pulsating stress (0·2 per cent deformation) on hardness and depth of cemented layer

control the compression deformation, a tube was mounted between the table and crosshead of the machine and loaded with a load of 2 tons and the specimen (through an extension piece) rigidly screwed in the machine under no load, so that it only endured the pulsating length changes regulated by the tube. The specimen was rigidly attached when the furnace was at 500 deg. Cent. The pulsations (500 alternations per minute) started at 600 deg. Cent. and continued during cementation. The depth of the case produced was determined by microscopical examination and micro-hardness testing of sections from the middle of the specimens. Carbon content was estimated by micro-analysis at intervals of 0·1mm. Some illustrations are reproduced from the more detailed diagrams given in the paper.

The first series of experiments at 900 deg. and 950 deg. Cent. showed the influence of push-pull alternations of 0·2 per cent on depth of penetration. Micro-hardness tests of the cemented layer showed that under pulsating deformation there was increased carburisation, and that this increase became greater with increasing temperature of cementation (Fig. 1). The increased absorption and penetration of carbon was confirmed by micro-examination and by micro-analysis of carbon content (Fig. 2). The effect of different degrees of deformation was examined. Pulsations giving length changes of 0·05, 0·10, 0·20, 0·50 and 1·0 per cent were applied, heating and cooling conditions being the same. With increasing degree of deformation up to 0·2 per cent there was an increase in depth of cementation. With 0·5 and 1·0 per cent

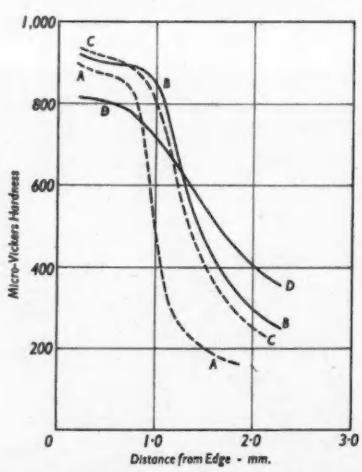


– – – – – – Unstressed. ——— Under pulsating stress. Carburised 9½ hours at 950 deg. Cent.

Fig. 2—Effect of pulsating stress (0·2 per cent deformation) on carbon content of cemented layer

deformation the carbon content at the surface was reduced but there appeared to be greater penetration towards the core. The hardness (maximum about 760) did not reach so high a figure at the edge but fell more gradually towards the core. Higher deformations than 1 per cent could not be studied as the specimens broke.

In further tests a static deformation of 1mm (2 per cent) was applied before and during carburisation under pulsating stress. In one case the specimen was stretched 2 per cent before cementation and then carburised for 4½ hours at 950 deg. Cent. under pulsating stress. In the

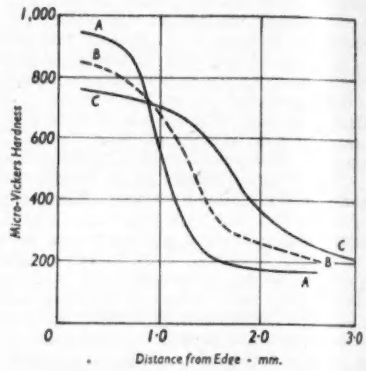


Carburised 4½ hours at 950 deg. Cent. *A*—Unstressed. *B*—Under pulsating stress. *C*—Stretched 2 per cent before carburising as in *B*. *D*—Stretched 2 per cent 1 hour after start of carburising as in *B*.

Fig. 3—Influence of a single deformation before or during cementation under pulsating stress (0·2 per cent deformation)

other case it was carburised for 1 hour at 950 deg. Cent., then stretched 2 per cent and cementation continued up to 4½ hours. Deformation before carburising had little effect, but a 2 per cent stretch during carburising resulted in lower hardness (800) and a more gradual fall (Fig. 3) like the effect of 1 per cent deformation in the previous tests under pulsating stress.

It appears that as a result of application to the specimen of a pulsating treatment, giving increased deformation up to a certain limit, the depth of carburisation is increased. The micro-structure indicated that the grain boundaries were the main channels of diffusion. Permanent deformation during cementation appeared to hinder surface carburisation, though diffusion continued to be more rapid under pulsating stress. This effect on diffusion was also shown in another way. Cemented specimens were



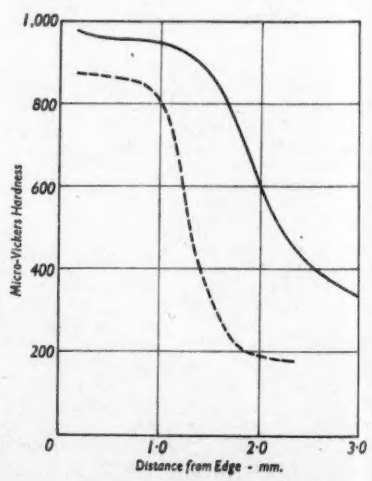
A—Not annealed. *B*—Not stressed during annealing. *C*—Annealed under pulsating stress (0·2 per cent deformation).

Fig. 4—Effect of pulsating stress on the result of annealing (for eight hours at 950 deg. Cent.) specimens carburised for 4½ hours at 950 deg. Cent.

annealed for 8 hours at 950 deg. Cent. unstressed and under a pulsating stress giving 0·2 per cent deformation. Micro-structure and hardness (Fig. 4) showed increased depth of penetration. Annealing lowered the surface hardness from 930 to 850 and raised the hardness at 2mm below the surface from 190 to 250. With the addition of pulsating stress the corresponding figures were 755 and 350. This again confirmed that under pulsating stress the diffusion process is accelerated.

Cementation Under Ultrasonic Treatment

To investigate the influence of high-frequency small elastic stresses, cementation was carried out under ultrasonic treatment (frequency 430kHz, output 300W or 6·5W/cm²). Special cementation equipment was constructed to



– – – – – – Unstressed. ——— Under ultrasonic vibration. Carburised 9½ hours at 950 deg. Cent.

Fig. 5—Effect of ultrasonic treatment during carburising on the hardness and depth of the cemented layer

carburise (for 9½ hours at 950 deg. Cent.) the upper end of a specimen, 500mm long, the lower end being in contact with a quartz oscillator immersed in water at 19 deg. Cent. Penetration as shown by microstructure and hardness tests (Fig. 5) was substantially increased. Annealing under ultrasonic vibrations also resulted in greater equalisation of carbon content than was obtained by ordinary annealing.

Nitriding and Chromising Under Pulsating Stress

Supplementary tests were made in nitriding and chromising with no attempt to follow established procedure but merely to ascertain the effect of pulsating stresses on nitrogen and chromium diffusion. The same 0·06 per cent carbon steel was used. The nitrogen experiments were made on a specimen 12mm diameter and 50mm acting length, bored with a hole 6mm in diameter for the passage of ammonia. Nitriding was carried out at 580 deg. Cent. for 30 hours with or without pulsations (500 per minute), giving 0·1 or 0·2 per cent deformation. The microstructures clearly showed a marked increase in depth of the nitrided layer produced under pulsations of 0·1 per cent and a further increase when the deformation was 0·2 per cent.

Chromium diffusion was studied by chromising the same steel with chromium powder (chromium powder 85, aluminium powder 5, granulated zinc 10 per cent) for 10 hours at 900 deg. Cent. or by annealing steel with a 0·2mm thick electrodeposit of chromium. By simply heating in chromium powder a chromised layer only a few hundredths of a millimetre was formed, whereas under pulsations a much thicker layer was obtained. The second method was ineffective. On simple heating no diffusion of chromium occurred and under pulsating stresses the chromium layer was damaged and broke away.

Ageing Processes Under Alternating Stress

The properties of the 0·06 per cent carbon steel after quench-ageing and strain-ageing under different conditions are first described. Mechanical properties are given in detail, electrical, magnetic and damping characteristics are also referred to, and the results of microscopical

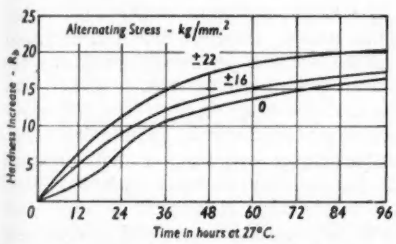


Fig. 6—Effect of alternating stress on the quench-ageing of steel containing carbon 0·06, nitrogen 0·018 per cent, quenched from 680 deg. Cent.

examination described. The influence of alternating stress in quench-ageing was investigated by rotary bending, pulsating push-pull tests and ultrasonic vibrations. Ultrasonic treatment during quench-ageing at room temperature was applied with the same equipment as before. At this temperature, with ageing times up to 240 hours, no difference in the rate or extent of the increase in hardness could be detected as a result of exposure to ultrasonic vibrations. On the other hand, the increase in hardness was more rapid under the influence of an alternating bend stress (3500 r.p.m.) and increased with increase of alternating stress (Fig. 6). Precautions were taken to ensure that the unstressed specimen was kept at the same temperature as the rotating one. Study of the influence of push-pull alternations (500 per minute) producing deformations of 0·05 and 0·10 per cent gave similar results but there is a possibility that these are affected by strain hardening. Experiments on the influence of alternating stress on the precipitation hardening of "Duralumin" similarly showed a reduction of the time of hardening with increase in alternating bending stress. Push-pull alternations also caused an acceleration in the hardening process as compared with that occurring in unstressed specimens.

This investigation is an important contribution to a subject on which previous data have been somewhat conflicting.

References

[1] *Comptes Rendus*, 1930, Vol. 191, page 1328.
[2] *Archiv f.d. Eisenhüttenwesen*, 1932–33, Vol. 6, page 241.
[3] *Archiv f.d. Eisenhüttenwesen*, November–December, 1954, page 579.

Creep of High-Purity Nickel

An item in the programme of the U.S. National Bureau of Standards is a study of the mechanism of creep in metals of high purity—for example, copper and nickel, and in binary alloys of these metals. Creep in high-purity copper was dealt with in papers published in 1950 and 1951.* A study has now been made by W. D. Jenkins, T. G. Digges and C. R. Johnson† of the creep behaviour in tension at 300 deg., 700 deg., 900 deg. and 1200 deg. Fah. of initially annealed, high-purity nickel, the influence of rate of loading to the selected creep stresses on creep behaviour, and the effect of prior strain history on the tensile properties of the nickel at room temperature. Microstructures were correlated with creep and tensile behaviour.

The material used for most of the tests was not of outstanding purity, but contained 99·85 per cent of nickel, the chief impurities being silicon 0·11, iron 0·04 and manganese 0·03 per cent. It was induction melted, cast into 14in by 14in by 60in ingots, forged to 8in by 8in blooms and hot rolled to 2½in square billets. These billets were hot rolled to ⅞in diameter bars, which were annealed for sixteen hours at 600 deg. Cent. and then for eight hours at 538 deg. Cent.

Discontinuous flow was observed in creep at each of the temperatures studied. The magnitude and position of the discontinuities, in the form of sharp serrations in the creep-rate/extension curves, varied with the temperature of the test, and were affected by such factors as strain hardening, strain ageing, recovery, Curie point behaviour, recrystallisation and grain growth. As the testing temperature was raised, the creep curves were affected by these factors in succession. The resistance of nickel to plastic deformation, as shown by the yield strength, diminishes with increase in temperature, though short-time tensile tests at 300 deg. and 700 deg. Fah. give higher tensile strengths than at room temperature. Although the resistance of nickel to creep increased as the testing temperature diminished, its resistance was especially high at a temperature of 300 deg. Fah. (149 deg. Cent.). This high resistance was attributed to a combination of strain age hardening and a relatively low rate of recovery. The phenomenon of strain ageing was especially prominent in the creep tests carried out at 300 deg. Fah., but was evident at higher temperatures also. Jaggedness shown in the curves for specimens tested at 700 deg. Fah. (371 deg. Cent.) was possibly accentuated by the nearness of the Curie point (380 deg. Cent.) as a discontinuity in elastic modulus is said to occur at that temperature. The discontinuities appeared to increase in magnitude with decrease in stress both at 700 deg. and 900 deg. Fah. (371 deg. and 482 deg. Cent.). The curves for specimens tested at 1200 deg. Fah. (649 deg. Cent.) were representative of the effect of stress in the recrystallisation region, strain hardening being followed by continuous recovery, the recrystallisation by grain growth, and by creep of the larger grains.

In the first stage of creep, the slope of the logarithmic creep-rate/time curve at 300 deg. Fah. was independent of stress within the range 14·3 to 19·2 tons per square inch, but increased with further increase in stress. At 700 deg. Fah. the slope was independent of stress over a more limited range. At 900 deg. Fah. the curve showed a continuous increase in slope with increase in creep stress. At 300 deg. Fah. the initially annealed nickel had a high resistance to creep up to 45,500 lb per square inch, but with a further increase in stress of 500 lb per square inch the creep rate increased by a factor of 10^5, as shown by the following figures :—

Creep Tests at 300 deg. Fah. (149 deg. Cent.)

Creep stress		Plastic extension, at zero time, per cent	Average creep rate, per cent per 1000 hours
Lb/in²	Tons/in²		
42,660	19·05	21·7	0·0007
45,000	20·10	32·0	0·0011
45,500	20·32	34·5	0·01
46,000	20·54	35·4	2100

No microscopical cracks were observed at the initiation of the third stage of creep.

Room temperature tests were made on material which had undergone creep at 900 deg. Fah. The yield and tensile strengths of such specimens increased with amount of prestraining in creep. The increase in strength was accompanied by a decrease in elongation though the total elongation (creep plus tensile) increased greatly whilst the total reduction of area was independent of prior strain history. The hardness at room temperature of specimens fractured in creep at 300 deg., 700 deg. and 900 deg. Fah. increased with increase in deformation in the vicinity of complete fracture. This trend was also observed in specimens tested at a relatively high secondary creep rate at 1200 deg. Fah., but with slower rates at this temperature the hardness decreased as the deformation increased in the vicinity of the fracture. Recrystallisation, accompanied in some cases by grain growth, occurred in specimens fractured in creep at 1200 deg. Fah., but no evidence of recrystallisation was detected in a metallographic study of specimens fractured in creep at lower temperatures. Fractures were predominantly transcrystalline at 300 deg., 700 deg. and 900 deg. Fah. and intercrystalline at 1200 deg. Fah.

The ductility at fracture was relatively high for all creep conditions. Only one specimen, tested at 1200 deg. Fah., at a slow secondary creep rate, gave evidence of brittle fracture. In all other specimens, fracture was preceded by appreciable necking.

The investigation serves to show the great importance to be attached to strain-age-hardening phenomena in interpreting the creep behaviour of nickel at raised temperatures. The prior strain history of the metal had a marked effect on the second stage of creep. To achieve uniformity of experimental results, the rate of loading to the creep stress employed had to be carefully controlled.

Crystalline Texture of Rolled Aluminium

A recent publication of the French Air Ministry deals with the crystalline texture or preferred orientation developed on rolling monocrystalline plates of 99·99 per cent aluminium.* In a rolled plate the texture is complex and varies from one layer to another. It may vary over a minute distance, so that the examination of a layer 0·1mm thick may only give the mean texture of the layer examined. In this study micrographic examination of etch pits and, more especially, diffraction patterns produced by X-rays at grazing incidence were used to follow the development of texture in individual layers in the course of reductions of up to 95 per cent in thickness. In general, the evolution of the texture was due to slip, varying from layer to layer in relation to the distribution of stress, but rotation of particles also occurred. After a reduction in thickness of about 85 per cent, a double texture or more rarely a complete break up of texture was observed.

Superposition of the polar diagrams obtained with specimens rolled from plates of different initial orientation gave a polar diagram comparable with that of polycrystalline plates. The preferred orientation of polycrystalline material was shown to arise from the greater frequency of certain average orientations rather than from the firmly established position of particular crystallographic axes.

* *Journal of Research*, U.S. National Bureau of Standards, 1950, Vol. 45, page 153; 1951, Vol. 47, page 272.
† *Ibid.*, December, 1954, page 329.

* "*Etude des textures cristallines obtenues par laminage progressif de monocristaux d'aluminium*" by Jack Manenc, Publications Scientifiques et Techniques du Ministère de l'Air, No. 293. Magasin C.T.O. : 2, Avenue de la Porte-d'Issy, Paris (15e). Price 1400 fr.

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DEFENCE AND THE SERVICES

In its Statement on Defence, 1955, the Government gives a clear lead to the other N.A.T.O. Powers by emphasising its belief in the great deterrent value of nuclear weapons and in the paramount importance of building up stocks of all kinds and a V-bomber force to deliver them. Indeed, it was scarcely necessary to emphasise to British readers the vast destruction resulting from nuclear warfare. They would have preferred to be convinced that every possible step was being taken to provide the most effective defence against the hydrogen bomb; and in this respect the White Paper is far from satisfactory. The first squadrons of V-bombers—our contribution to the deterrent—are to be in service this year, but if the deterrent fails to deter it is small comfort to read that "the development of new fighter aircraft has been passing through a stage of great difficulty." Our fighter strength is, in fact, grossly inadequate to deal with the scale of bomber attack to be expected against this country in the early stages, and the guided missile situation is even worse. United States Navy and Air Force fighters are already equipped with air-to-air missiles; and 100 sites for batteries of four ground-to-air guided missile launching platforms are in process of erection for the defence of U.S. major cities and industrial areas. The fact that the Americans started three years before us does not explain why no air-to-air guided missiles have yet been issued to our Armed Forces and no ground-to-air missiles are in production. Even so, if, as we believe, the menace from thermo-nuclear missiles is no less serious than the danger facing us in 1951 from Russian conventional forces, we could surely have afforded to purchase a supply of American ground-to-air missiles for the protection of our most vital areas. At £1494 million the Defence Budget for 1955–56 is again reduced—£60,000,000 less than for last year—in spite of considerable underspending on production Estimates during the past two years.

Allowing for American aid and receipts for supplies and services to other Governments, the Navy Estimates at £340½ million show a reduction of £12½ million on last year. The Navy is, in fact, marking time, waiting for the guided missiles and other new weapons now in prospect. Apart from resumption of work on the three "Tiger" class cruisers, no provision is made for the construction of new large ships. Action is, however, being taken to enable a start to be made at the earliest practicable date on the construction of a class of guided missile ships to replace our older cruisers. But there is little likelihood that any of these vessels will be laid down for another two years, as the trials of the "Girdleness"—now under conversion as an experimental guided missile ship—are not planned to begin until 1956. The guided missile armament in these ships, it should be noted, is intended for anti-aircraft defence only. Reliable long-range guided missiles suitable for firing from ships at ship or shore targets are not yet on the immediate horizon. The "Regulus" and "Matador" missiles, now in service in U.S. submarines and in the U.S. Air Force respectively, have a range of 500 miles, but they are subsonic winged missiles (V-1's) and thus no less likely than piloted aircraft to be shot down by anti-aircraft fire. The two heavy U.S. cruisers which will shortly rejoin the Fleet after conversion for guided missile firing still retain their forward guns as their main armament; and, in his memorandum accompanying the Navy Estimates, the First Lord makes it clear that the British ships now visualised will follow the same pattern. They will, however, be so designed that their gun armament can be replaced by the ship-to-ship guided weapon as soon as it becomes available. Two fleet escort ships with destroyer characteristics, eight new general-purpose frigates and ten more coastal minesweepers are to be ordered this year. The Reserve Fleet is to be radically reorganised, special attention being paid to ships which are, or can be, made ready for almost immediate service. These will be refitted and maintained at the shortest possible notice. Their maintenance will be carried out principally in private shipyards. Great importance is attached to the heavy carrier as the core of a modern fleet and the present all-weather "Sea Hawk" and "Venom" fighters will in due course be replaced by the "N113" (a development of the "Supermarine 525" swept-wing twin jet) and the "D.H. 110." The "Wyvern" is not considered satisfactory as a strike fighter and is to be replaced by an aircraft of far greater range and speed, capable of carrying atomic bombs. They will, however, be for use at sea and there is no intention of following the Americans in building super carriers of 60,000 tons to operate heavy medium-range bombers against inland targets. The Army Estimates at £474 million are less by £61,000,000 than last year. These figures allow for U.S. aid without which the reduction would have been £77,000,000. Like the Navy, the Army is marking time and, with the completion of the programme for the supply of new wheeled vehicles, less is to be spent on weapons and equipment. The main weapons for which provision is made are the new Conqueror tank—to reinforce the Centurion; the new L70 light anti-aircraft gun (a power-controlled 40mm Bofors with improved rate of fire and ceiling) to deal with low-flying aircraft; the self-loading F.N. rifle, of which 5000 have already been issued for trial; and the new sub-machine gun. There is also a comprehensive programme of new wireless, bridging and ferry equipment, and, in his explanatory statement, the Secretary of State for War refers to the need for providing for a surface-to-surface guided missile for use in the field—presumably the U.S. "Corporal," now under trial in the British Army. He adds that it is urgent to simplify weapon systems, to reduce the number and variety of vehicles and to simplify and speed up supply. The division is likely to remain the basic fighting formation, but its detailed organisation and equipment will be radically changed with the introduction of nuclear weapons.

The Air Estimates—at £514 million—are £22,250,000 more than last year. This, however, takes into account U.S. aid, which was substantially larger for 1953–54; the true increase is little more than £3,000,000. Much greater provision is to be made for fighter aircraft and our all-weather squadrons are expected to receive their first "Javelins" during the year. Some of these squadrons are being re-equipped with "Venom" night fighters. The first squadrons of Hawker "Hunter" day fighters—which still have development difficulties—have now been formed, but no hint is given of when the English Electric "P.1" may be expected. The Royal Auxiliary Air Force will, after all, retain their full establishment of "Meteor" and "Vampire" fighters, but in accordance with the new policy their pilots will have opportunities to train on high-performance aircraft in associated squadrons. The Secretary of State for Air, in his explanatory statement, gives high praise to our control and reporting system, which is to be linked more closely with radar systems in Conti-

nental countries. Our radar chain has been reconstructed and now covers the whole of the United Kingdom. Hundreds of new installations have been built and vital parts of the system have been put deep underground and protected by massive thicknesses of concrete. Much effort has also been expended in providing runways for operating V-bombers and the new fighters, and there is a promise of the return to private ownership of a large number of disused airfields not likely to be suitable for modern war conditions. Orders have been placed for the Vickers "1000" long-range jet transport to provide increased mobility for land and air forces and for the "Comet II" which will in the meantime give experience to Transport Command in operating high-speed jet transports.

POWER FARMING PROBLEMS

During the last decade much has been said about the rapid progress of agricultural mechanisation in this country. It is progress which has made a notable contribution to the productivity of the farming industry, even though mechanisation has not caused two blades of grass to grow where one grew before. Yet mechanisation has eased the hard labour hitherto involved in many farming tasks; it has enabled important seasonal operations, like seed-time and harvest, to be speeded up, and has thus helped farmers to make the most of such favourable weather as has appeared in the somewhat unpredictable climate which this country suffers! The number of machines and implements which have been designed and developed for operation by the power take-off, hydraulic lift, or the belt-drive of a tractor is well-nigh legion. The production of those machines has increased year by year, sales of them at home, and overseas, have become more and more extensive, and thought of the amount of capital invested in machinery by the farmers of to-day would undoubtedly cause their grandfathers to turn in their graves. It is doubtful if upon any other of this country's industries mechanisation has made such a spectacular and speedy impact as it has upon agriculture. The whole process has been marked by a readiness on the part of engineers, including research engineers and designers, to do their utmost to produce machines and implements as well suited as possible to the many different jobs that efficient farming involves. Farm machinery no longer consists—if it ever did—of a collection of improvised "gadgets"; it has been thoughtfully and scientifically evolved.

But in some quarters it is being suggested that the mechanisation of agriculture is now approaching its zenith, if it has not already reached it. Certainly the economics of farm mechanisation is receiving more searching study than it did in the years immediately after the war. Moreover, many of the present generation of farmers, having grown away from the traditional prejudices of their forefathers towards "new-fangled" things, are apt to become increasingly critical of the machines available to them. It is possible, of course, that, appreciating the benefits accruing from mechanisation, many farmers are now beginning to expect too much all at once! There was evidence of this, we feel, in the discussions at the fifth annual National Power Farming Conference which we recently attended at Harrogate. There, for three days, a company of several hundreds of agricultural machinery designers, manufacturers and dealers and farmers exchanged views on many aspects of "power farming" as mechanised agriculture is now frequently called. The discussions were based on a series of fourteen papers, most of which were contributed by engineers and farmers, but which included one by a time-and-motion-study expert. Two of these papers in particular struck us as being of special importance to engineers. One was presented by Mr. Frank Henderson, a farmer, under the title of "Profit or Loss on Machinery," and the other, by Mr. R. Hall, an engineer, was entitled "A Mechanical Engineer Looks at Farming." Both papers were in a measure critical of farm machinery—apart from the tractor. Mr. Henderson claimed that agricultural mechanisation involved "worry and trouble quite apart from any financial consideration," and he went on to talk of his neighbours with highly mechanised farms who at harvest time "did very little but wait for something to break." He added that he had been buying new machinery for over thirty years and had "yet to have a machine delivered which could be used effectively without some alteration, adjustment or repair before it could start work." Mr. Hall, on the other hand, speaking as an engineer with considerable experience in the food manufacturing and processing industry, was critical of the production techniques of agricultural machinery makers. He did suggest, however, that as a result of the very rapid development of mechanisation during the last twenty years, "power farming has become a business calling for a very much greater degree of skill and intelligence than is at present apparent."

A comment of that kind is in no sense a slur upon the diligence of those who work the land and who are skilled and experienced in the arts and mysteries of agriculture. It does, however, emphasise that no machine can perform efficiently if it is not carefully and intelligently used. In the discussions at Harrogate on the two papers we have mentioned, and on others, engineers were freely and frankly criticised about the design and performance of their products. But we heard all too little from the users of farm machinery about their methods and standards of operation and about such important matters as the housing, general care and maintenance of their machines. Engineers are not sensitive about the criticism that may be levelled at them; they are indeed at all times ready to profit by it. None-the-less, there are some occasions when the customer is not always right! Power farming at present may be facing some new problems, but British agricultural engineers have established a record and a reputation of which they need not be ashamed. Their reputation will be further enhanced if they persevere in the task of encouraging, by the various means at their disposal, the more intelligent and thoughtful utilisation of the machines and implements, in the design and production of which their skill is so ably demonstrated.

IRON AND STEEL DEVELOPMENT PLAN

The report on the development of the British iron and steel industry, which was briefly reviewed in our last issue, sets out the reasons for, and the details of, the industry's second post-war modernisation programme. It has been prepared by the Iron and Steel Board, after consultation with all the interests concerned, and deals with the five-year period 1953 to 1958. When the Board was set up in July, 1953, it had before it an outline of this second development plan, which resulted from surveys made by the British Iron and Steel Federation and by the Iron and Steel Corporation of Great Britain during the nationalisation period. The modernisation and expansion schemes suggested in the light of those surveys were based upon the expectation that by 1957–58 the annual demand for steel would be of the order of 21,000,000 ingot tons. Since the Iron and Steel Board took office, it has made a full examination of the situation, with the result that the industry has now set its sights somewhat higher. In this second post-war development programme, an annual steel requirement of 22,500,000 tons is envisaged by 1958.

The first post-war programme of steel development, which was determined upon in 1946, involved the industry in a capital expenditure of about £310 million. Despite the many economic difficulties of the immediate post-war period, the modernisation and expansion projects set out in the programme were virtually completed in the short space of six years. The result was that steel output, which had been 12,695,000 tons in 1946, had progressively increased by 1953 to 17,608,000 tons. During that period, the iron and steel industry had to suffer a great deal of uncertainty as to whether it would be permanently nationalised, or whether it would be permitted, as in the event was happily proved, to continue its course under private ownership with a measure of public supervision. The industry, nevertheless, did not deviate from its development plans, and most of the projects detailed in this second programme are already well in hand. Major schemes are in progress at twenty-five different steel works, the total expenditure on them being estimated at about £257 million. With further schemes which will doubtless receive approval in the next few years, but which will mainly influence production after 1958, expenditure on development in the five-year period dealt with in the report is expected to exceed £300 million. Certainly, the fulfilment of this second development plan, which is, after all, a natural continuation of its predecessor, will ensure the maintenance of the already firm structure of the British iron and steel industry. It will do more than provide additional modern plant; it will add considerably to the efficiency of an important basic industry, whose productivity record since the end of the war is a very impressive one.

Books Received

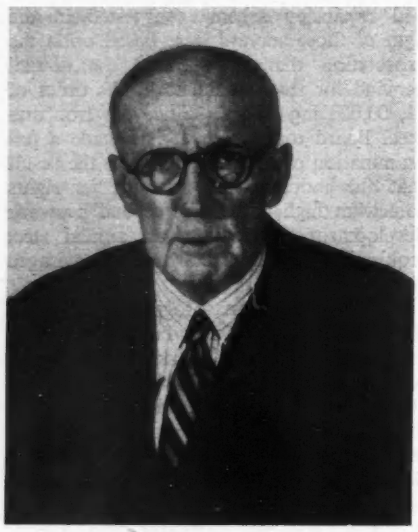
An Introduction to Cost Accountancy. Volume III. By R. W. Dobson. London: Gee and Co. (Publishers), Ltd., 27–28, Basinghall Street, E.C.2. Price 37s. 6d.

Theory of Machines Through Worked Examples. By G. H. Ryder. London: Cleaver-Hume Press, Ltd., 31, Wright's Lane, Kensington, W.8. Price 18s. 6d.

Obituary

SIR STEPHEN J. PIGOTT, D.Sc.

THE news of the death of Sir Stephen Pigott, which occurred on Sunday, February 27th, at his home, Closeburn Castle, Thornhill, Dumfriesshire, will have been received with considerable regret by marine engineers in this country. Sir Stephen, who became resident in Great Britain in 1908, was born on January 30, 1880, at Cornwall, in New York State, and some 60 miles north of New York. He received his early education at the High School in his home town and then spent the next three years gaining engineering experience with a number of firms, including



Sir Stephen J. Pigott

the Columbia Electric Vehicle Company and the E. W. Bliss Machine Shop, Brooklyn, before proceeding to Columbia University. Here he studied mechanical and marine engineering and took his degree in 1903. During the following five years he acted as assistant to Mr. Charles G. Curtis in the development of the impulse turbine for marine propulsion, and then in 1908 he was invited by the Admiralty to come to Great Britain. A few months after his arrival in this country Stephen Pigott became associated with John Brown and Co., Ltd., as a specialist in impulse turbine work and so began his connection with the famous Clydebank firm which was to last for forty years until his retirement in 1948. From his work on the impulse turbine developed the Brown-Curtis turbine, which was adopted by the British Admiralty and was installed as the main propelling unit for a number of passenger liners engaged in the North Atlantic and other services. His promotion was rapid and he became manager of the engine works, and his value to the company was recognised by his being appointed a local director in 1920. In the ensuing years, Sir Stephen worked in close association with the late Sir Thomas Bell and in 1934 he was made a full director of the company, and then a year later he succeeded Sir Thomas Bell as managing director, a post which he continued to hold until his retirement, due to ill health, in October, 1948.

Many changes took place in marine engineering theory and practice during the period Sir Stephen was at Clydebank and he was associated with and responsible for the engines installed in a large number of naval and merchant navy ships. Among such can be mentioned the battle cruisers H.M.S. "Tiger" and H.M.S. "Hood," the battleships H.M.S. "Barham" and H.M.S. "Vanguard," the Canadian Pacific liner "Empress of Britain," and that company's "Duchess" class liners, and many Cunard liners, including the "Aquitania," "Caronia" and the "Queen Mary" and "Queen Elizabeth." With regard to the construction of the first of the large Cunard liners, he read a paper before the Institution of Naval Architects in 1937 entitled "Some Special Features of the 'Queen Mary.'" Sir Stephen's energy and skill contributed greatly to the progress made in marine engineering, and his work was recognised when he was awarded, in 1938, the Gold Medal of the American Society of Mechanical Engineers for his outstanding leadership in marine propulsion and construction. Two years earlier his own university had recognised the value of his work and conferred upon him the Honorary Degree of Doctor of Science. His distinguished services to the advancement of engineering were rewarded when he received a Knighthood in 1939, and in the following year—1940—he received the Parsons Medal. In connection with the latter award, Sir Stephen delivered the Parsons Memorial Lecture before the North-East Coast Institution of Engineers and Shipbuilders, taking as his subject "The Engining of Highly Powered Ships." He was an active member of many of the technical societies, including the Institution of Mechanical Engineers, the Institution of Naval Architects, of which he was elected a vice-president in 1941; the Institute of Marine Engineers, of which he was president in 1937/8, and the Institution of Engineers and Shipbuilders in Scotland. From 1933 until 1952, Sir Stephen was a member of the Technical Committee of Lloyd's Register of Shipping, and he also served on the General Committee from 1936 until he retired in 1952. He was a member of the Worshipful Company of Shipwrights and a J.P. for Glasgow, and his death will be keenly felt by his many friends in the shipbuilding and marine engineering industry.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

HIGH-SPEED ELECTRIC AND DIESEL-ELECTRIC TRAINS

SIR,—It will be remembered that in February of last year, a French electric locomotive, S.N.C.F., No. CC7121, hauling three coaches, covered the 23 miles from Dijon to Beaune in 15 min, start to stop, at an average speed of 92 m.p.h., at one point midway, near Vougeot, reaching a maximum of 151 m.p.h., the highest speed ever recorded on rails. During a recent visit to France I rode over this stretch in the cab of the same type of electric locomotive, hauling "Le Mistral," France's premier train, which runs between Paris and Marseilles, electrically hauled as far as Lyons, and steam hauled—by the very fine Chapelon four-cylinder compound 4–8–2s, "P241" class—thence to Marseilles. The cab of an electric locomotive, with its perfect "look-ahead," is a fine vantage point from which to judge track layout and condition, and I could not help being much impressed by the perfection of everything seen as the 1000-ton train swept along at over 80 m.p.h. hour after hour. It was impossible to imagine finer permanent way and equipment, and it is not surprising that some of the fastest trains in Europe run over this route. From Lyons to Marseilles the track is not quite so good; one notices it at once from the cab of even as fine riding engines as the 4–8–2s, but no attempt has as yet been made to bring this stretch up to the same standard as the northern part of the route, nor will this be done until the whole distance through to Marseilles is electrified.

During one of many pleasant talks with Monsieur Segaud, the Chief of Design, S.N.C.F., congratulating him upon this super-high-speed running, he appropriately enough electrified me by saying that it was intended to leave this performance far behind in the near future. My immediate reaction was to ask if he was serious; he assured me he was, explaining that in February of this year, 1955, it was intended to reach a speed of 350km, or 214 m.p.h. over a stretch of track that was to be prepared near Bordeaux. Preparations were already being made—our chat was last September—and everyone was confident that the aims would be reached. The engine—and presumably the train—would be streamlined, which was not the case with the 151 m.p.h. test. A venue near Bordeaux had been chosen because there the track was both level and straight, and better suited to extreme velocity than between Dijon and Beaune.

So intrigued by all this, I forgot to ask the purpose of the experiments, as, after all, such colossal speed does not at first sight seem practical politics on ordinary track; or, in fact, on rails at all, the air appearing more suitable. But the S.N.C.F. would not be likely to go to all the trouble and expense involved without good reason, and no doubt we shall hear what this is in due course. In any case, it is one more sign of the times—the passing of the steam locomotive in France, to make way for complete electrification.

In North America, both as regards Canada and the States, the passing of the steam locomotive is also taking place, and has in fact proceeded much farther than in France, though "dieselisation" is the plan as opposed to electrification. After several decades of static timing, the Canadian trans-continental trains have been substantially speeded up, largely as a result of the newer form of motive power. The C.P.R. has just announced that, beginning in April, the "Dominion" train will cover the 2881 miles from Montreal to Vancouver in 71 h 10 min, a reduction of 16 h over the present schedule, which makes the average speed 40·5 m.p.h. This is more creditable than would appear at first sight, as apart from the great distance covered and the unforeseeable things that may happen *en route*, the greater part of the 600-odd miles stretch through B.C. is quite unsuitable for high speed, so it follows that the running average for the rest of the distance will be upwards of 50 m.p.h. Moreover, stops will take up several hours. Going eastward from Vancouver the time will be cut even more, to 70 h 20 min, an average of 41 m.p.h. Altogether a great advance over the timing that has existed for so many years.

The Canadian National Railway is following suit, though somewhat more tardily, in completely "dieselising" its transcontinental services, and will no doubt reduce its through timing to correspond with that of the C.P.R. This it should be able to do quite easily, its track being of more recent construction, laid down with far easier gradients, and, springing from a combination of Canadian Northern and Grand Trunk Pacific routes, the best of the two was chosen where possible. Over most of the main line there are very easy gradients, where there are any at all; through B.C., for instance, threading the Province's sea of mountains and canyons, the ruling gradient is only 1 in 330, making double-heading unnecessary. Conditions are very different over the C.P.R. route.

Returning to the Pacific coast recently, I found the "Dominion" diesel-hauled right through from Montreal to Vancouver, with some of the new "Dome" cars included in the rolling-stock. By the Spring, no doubt to

coincide with the faster schedule, the whole train will be dome-equipped. Between Edmonton and Calgary, "Budd," one and two-unit direct-drive diesel cars are running in place of the former 4-4-4 type steam locomotives of the "3001" class. Enginemen with whom I rode on both kinds of power were unanimous in approving of the change, and while I could enter into their feelings, as an observer I could not entirely share them—I would as lief ride a tram!

E. H. LIVESAY

Victoria, B.C.,
January 29th.

COLLIERY CONVEYOR BELTS

SIR,—In your leading article on "Mines Inspection" (Vol. 199, No. 5168, February 11, 1955) the statement is made that "separation of the plies in P.V.C. belting has been the most frequent cause of failure with this type of belting hitherto."

Experience has now shown that P.V.C. does not possess the properties that give satisfactory ply adhesion in rubber-and-canvas beltings, but it should be realised that, in fact, the problem has been successfully overcome by its development in beltings of solid woven construction. This type of belting is woven in one solid completely bound piece and without plies in the normal sense, so that ply separation is impossible. Full use can thus be made of the unique properties of P.V.C. material and after extensive mines use under all types of conditions, it is our opinion that the solid woven belt is now firmly established as a proven success and is probably the final answer to the search for a non-inflammable colliery conveyor belt.

S. B. HAINSWORTH
Managing Director,
Marfleet, Hull, J. H. Fenner and Co., Ltd.
February 15th.

SAFE WORKING LOADS OF ROPE BLOCKS

SIR,—I should be pleased if you will allow me to make a few comments upon the above subject in reply to Mr. G. Weston, whose letter appeared in your issue of December 24th. To begin, it is important that the meaning of the term safe working load should be clearly understood. The official definition taken from the B.S.S. is as follows:—"The safe working load shall be the maximum load which can be safely lifted by the block—not the imposed load on the top block." Mr. Weston states in paragraph (*a*) referring to the diagram on page 673, that "the resultant proof-load on the top block exceeds the proof-load on the bottom block by only 33⅓ per cent." This statement is entirely erroneous! If Mr. Weston will refer to B.S.S. 408 : 1931, he will find the following Note 2 on page 10:—"If blocks are reeved up for testing, the end of the rope shall be attached to an independent anchorage, such as the frame of the testing machine." If we carry out these official instructions, it follows that whilst the safe working load is 2, the proof-load on the bottom block will be 4 and the resultant proof-load on the top block will be 6, which is 50 per cent in excess of the actual proof-load applied and not 33⅓ per cent.

I note that we are in agreement that a pair of 4in by 2in 1 and 2 sheave blocks will carry a safe working load of 6 cwt. With the load taken on three ropes, the load per rope or the load on the becket is 2 cwt, the same as the 2 and 2 and 3 and 3 sheave. It follows in this case that the 1 sheave bottom block—identical to all other 1 sheave 4in by 2in blocks—carries a safe working load of 6 cwt and would therefore be tested to 12 cwt.

Referring to the question of the load on the becket of a 1 and 1 sheave block. If Mr. Weston will please check the following, he will find that the B.S.S. 408 states on page 11 that "each becket shall be capable of carrying half the load on any one sheave." This agrees with the figure on page 673 and should be sufficiently conclusive for anyone, but after a long correspondence with a member of the B.S.I. upon this point, I was able to convince him that this should be one-half and one one-third, and received a letter confirming this, an abstract of which is as follows:—"I did not reply to your letter of February 16th as we seemed to have reached a reasonable agreement and I did not wish to raise any further points of disagreement. As, however, you ask for a reply, I would say that I fully agree that the load on the becket of a 1 and 1 sheave block will be half the load lifted by the tackle."

Again, as the tension in the rope must be constant throughout in a supposedly frictionless system, it follows that the load on the becket must be equal to the tension in the rope and, as the load is carried on two ropes, the load on the becket must be half this load. Finally, Mr. Weston states that the standard does not deal with tackles, yet in the "Foreword" we find the following:—"Such blocks are used singly or in combination as a tackle and are of similar range to those in makers' catalogues."

G. H. BOOT

Harborne, Birmingham, 17.

Report of the Inquiry into London Transport

THE report of the Committee of Inquiry into London Transport was presented to Parliament last week. This committee was appointed in April last by the Minister of Transport to inquire into the conduct of the undertaking with a view to ascertaining what practical measures could be taken by the British Transport Commission and the London Transport Executive in order to secure greater efficiency or economy.

Some idea of the magnitude of the undertaking can be obtained by the figures given in the report. The Executive operates bus, coach and railway passenger services over an area of some 2000 square miles, and at the end of 1953 these services covered a road route mileage of 8129 and a railway route mileage of 223. The stock involved in serving these routes included 7201 double-deck buses, 893 single-deck buses, 372 coaches, 1797 trolley-buses, 4099 railway passenger cars and 1149 miscellaneous vehicles. During 1953 road and railway passenger vehicles ran some 634 million miles, 3658 million passengers being carried by road vehicles and 580 million passenger journeys being made on the railways. These figures are higher than for any other city passenger system in the world.

The general conclusion reached by the committee was that the standard of service provided by London Transport was high except for acute overcrowding during peak hours, poor interchange facilities between rail and bus services, and some irregular and slow running of bus services through crowded streets. A marked improvement in efficiency and substantial savings could be effected if its recommendations were to be put into operation. If, however, steps were not taken to improve the external conditions in which London Transport operates, and if certain internal reforms were not made, there was a serious danger that the standards of efficiency would decline and costs would rise with an inevitable reaction upon fares. It was not only necessary to maintain existing standards but to improve them. Any substantial reduction in these standards, to make possible reductions, or avoid increases, in fares, would lead to the increasing use of private means of transport and have an adverse effect upon traffic congestion which was already becoming critical.

A great contribution to the reduction of travel costs and improvement of services in London could be made by staggering working hours to eliminate peak travel periods in the morning and the evening. Traffic delays were very costly and the committee considered that congestion would get worse and the cost of operating buses in London would go on increasing unless action were taken to improve road layout and remove bottlenecks. A fresh and vigorous campaign was needed by all concerned to stagger working hours and it should be made clear that if the luxury of an inflated transport organisation was required there was no justification for complaint against the cost of the luxury service demanded.

In the parts of the report dealing with finances it is shown that the receipts of London Transport from all sources in 1953 totalled £70,210,000, and after deducting a contribution to central charges the deficit per vehicle mile was about 1½d. Since it commenced operations on January 1, 1948, London Transport Executive has incurred a deficit of about £12,500,000, and the committee considered that the trend of the results was not reassuring. The statutory procedure for fare increases causes a time lag between the costs and increases, which if it could be reduced would improve results. Between 1938 and 1953 costs rose by 130 per cent, whilst fares rose by only 78 per cent. If the fares had been increased for 1952 and 1953 to the extent to which the value of money had fallen, the committee considered that there would have been a large surplus in the years 1952 and 1953.

As a result of investigations into vehicle maintenance the committee considered that the cost was too high, and the numbers employed on repairs and maintenance of both rail and road rolling stock were excessive. Substantial economies should and could be effected to increase productivity per head in the overhaul works and in the garages. The new bus overhaul depot at Aldenham could be made a very efficient and relatively low cost maintenance works, but productivity was low because of the excessive number of hands employed. It was considered that inspections of road vehicles by the Ministry of Transport's certifying officers were meticulous to an extent that was unreasonable. At the Acton works where railway stock was overhauled, there was also room for improved productivity and reductions in staffing.

The report states that the indirect advantages to London Transport and to the economy of London as a whole of the new tube line Route C (described in THE ENGINEER of February 11, 1955) were so important that this project should not be abandoned or postponed because on the basis of revenue or direct expenditure it appeared unprofitable. Very heavy expenditure on roads would be necessary if the tube railways were unable to cope effectively with passenger traffic and new tubes might prove to be less costly than roads, and more effective in moving large numbers of passengers.

In dealing with the higher organisation of the London Transport Executive, the committee recommended that there should be not less than two part-time members with experience in fields other than transport. Recommendations were also made in connection with the introduction of co-ordination of services at a lower level than that of the Executive, and for a greater degree of decentralisation by giving more responsibility to the heads of the road services divisions and districts. The statutory position as regards relationship between the London Transport Executive and the British Transport Commission was unsatisfactory and for this reason one of two courses was recommended. Either the London Transport Executive should be reconstituted as an entirely separate body, or the executive as a statutory body should be abolished. In the latter case the functions of the executive would be vested in the British Transport Commission, which would have full control over the board of management appointed to replace the executive.

ST. ERIK'S FAIR, STOCKHOLM.—The thirteenth International St. Erik's Fair will be held in Stockholm from August 27 to September 11, 1955. This Fair was visited last year by over 360,000 people, including 84,500 buyers. At this year's Fair there will be a British pavilion of 20,000 square feet, which is likely to be the largest in the exhibition. The pavilion will have its own cinema and a special film service is available for making colour films with Swedish commentary for exhibiting and other firms. Full information can be obtained from Aktiebolaget S : T Eriks-Mässan, Stockholm 26, Lidingövägen 10, or from the sole agents in Great Britain, Thirza West Publicity, Ltd., 141, New Bond Street, London, W.1.

Report on the "Comet" Accidents

No. III—(*Concluded from page 265, February 25th*)

Abstracts from the Commissioner's report of the Court of Inquiry into the accidents to "Comet" G-ALYP and G-ALYY which was published, with illustrations, recently are here reproduced. The Commissioner was Lord Cohen, and the assessors were Sir William Scott Farren, Professor William Jolly Duncan, and Air Commodore Allen Henry Wheeler*

AS a result of the new search R.A.E. received a piece of cabin skin, which had been found by an Italian fishing boat. It was identified as coming from the centre of the top of the cabin approximately over the front spar of the wing (see Fig. 5)†. It contained the two windows in which lie the aerials which are part of the A.D.F. (Automatic Direction Finding) equipment.

Other parts provided important evidence about the bursting of the cabin. There were marks on them which were identified as made by pieces from the cabin itself. Taken together with the paint mark on the leading edge of the centre section not far from where the outer wing broke off, which was identified as caused by the piece of the cabin wall containing the first window (escape hatch) (see Figs. 6 and 5), they established that the cabin burst catastrophically in the neighbourhood of the front spar of the wing when the aircraft was flying substantially normally.

By examination of the piece containing the A.D.F. windows and the adjacent pieces (see Fig. 5) it was established that it was here that the first fracture of the cabin structure of "Yoke Peter" occurred. In general terms, it took the form of a split along the top centre of the cabin along a line approximately fore and aft passing through corners of the windows as shown in Fig. 7. The direction in which the fracture spread was determined by examination of the lines of separation of the material.

Apart from the area on top of the cabin around the A.D.F. windows, the remainder was recovered with, and in many cases remained attached to, either the front fuselage, the wing centre section, or the rear fuselage. In the light of all this evidence, I accept R.A.E.'s conclusion that the first fracture of the cabin occurred near the rear A.D.F. window and spread fore and aft from it.

I do not consider it possible to establish with certainty the point at which the disruption of the skin first began. But I consider that it is probable that it started near the starboard aft corner of the rear A.D.F. window, at a point where examination by experts showed that fatigue had existed, at the edge of the countersunk hole through which a bolt passed (see Fig. 8).

The only alternative point suggested was the opposite (port forward) corner of the same window. Here the fracture passed through a small crack in the reinforcing plate, about 0·2in long, made accidentally during the building of the aircraft. This had been dealt with by de Havillands in accordance with their procedure for dealing with any departure from the strict requirements of their drawings which might appear during the manufacture of their aircraft. All such matters were required to be reported to the Technical Office, and each was dealt with as a special case by a qualified expert. In this case approval was given to the use of the normal process of "locating" small cracks in the skin of an aircraft by drilling small holes at their ends. Advised by my assessors, I see no reason to doubt that this would have been a satisfactory method of dealing with the crack in question had it not been for the fact that the stress in this region was relatively high. It was suggested that such a crack might be a possible place of origin of fatigue but no witness was able to identify any evidence of fatigue at the material point.

It is my opinion that the fundamental cause of the failure of the cabin structure was that there existed around the corners of the windows and other cut-outs a level of stress higher than is consistent with a long life of the cabin, bearing in mind the unavoidable existence of points, within the areas of generally high stress, at which it will be still further raised by relatively local influences, such as the countersunk hole near the starboard rear corner, and the small crack with its "locating" hole near the port forward corner. I find it impossible to say, definitely, on any evidence before me, which of these operated first. But, since the existence of fatigue near the bolt hole is established, I think it the more probable.

[*Engine Investigation.*—Tests described in the report demonstrated that the damage to all four rotors (one was not recovered) was caused by gyroscopic forces initiated by rapid rotation of the wing after the cabin exploded.]

The R.A.E. Report

The report (which was part of the evidence before the Court) is divided into twelve parts. The first part contains an outline of the investigation and states the opinion R.A.E. formed as to the cause of the accident. I have included the first part, which is intelligible without reference to the other parts, as an appendix, which states the opinion of R.A.E. is in the following terms :—

"We have formed the opinion that the accident at Elba was caused by structural failure of the pressure cabin, brought about by fatigue. We reach this opinion for the following reasons :—

"(i) The low fatigue resistance of the cabin has been demonstrated by the test described in Part 3, and the test result is interpretable as meaning that there was, at the age of the Elba aeroplane, a definite risk of fatigue failure occurring (Part 3).

"(ii) The cabin was the first part of the aeroplane to fail in the Elba accident (Part 2).

"(iii) The wreckage indicates that the failure in the cabin was of the same basic type as that produced in the fatigue test (Parts 2 and 3).

"(iv) This explanation seems to us to be consistent with all the circumstantial evidence.

"(v) The only other defects found in the aeroplane (listed in Section 3) were not concerned at Elba, as demonstrated by the wreckage."

The "other defects" mentioned in sub-paragraph (v) quoted above are :

(*a*) Relatively low resistance of the wing to fatigue.

(*b*) Possibility of fuel from the fuel tank venting system entering the trailing edge area of the wing near the jet pipe shrouds.

(*c*) Risk of internal damage during refuelling to the outer wing tanks under conditions which, though abnormal, may sometimes have occurred in practice.

I shall return to these defects after I have stated my opinion on the major conclusion of the report.

The Court's Conclusions as to the Cause of the Accident

As I have already indicated and for the reasons I have given, I have accepted the main conclusion of the report that the cause of the accident to "Yoke Peter" was the structural failure of the pressure cabin brought about by fatigue.

The Alternative Suggestion Made by Mr. B. Jablonsky.—The only rival suggestion was made by Mr. Jablonsky. His experience of structural problems in aeronautics has been concerned mainly with propellers having blades of highly compressed wood. He is, therefore, familiar with adhesives, and with the problems which have to be overcome in using them to make components.

In the construction of the "Comet" wide use is made of a metal-to-metal adhesive known as "Redux," mainly for the purpose of attaching members, generally known as "stringers," to the skin both of the wing and of the cabin. In the cabin there are about forty stringers more or less evenly spaced around the circumference and running longitudinally. They are not structurally continuous from end to end, the largest uninterrupted length being about 25ft. de Havillands were pioneers in using "Redux" for such purposes in aircraft structures, and have had long experience of it. It is, in effect, an alternative to the conventional riveting.

Mr. Jablonsky's argument proceeded on the following lines :—

(*a*) The skin of the cabin is exposed under service conditions to a large variation in temperature. He suggested a range of 80 deg. Cent. on the ground in the tropics to −55 deg. Cent. at about 40,000ft. The rate of climb of the "Comet" is fairly high and the temperature of the skin might change over this range in about thirty minutes. The stringers, however, although inside the skin, are outside the insulating lining of the cabin and therefore not exposed to the full temperature of the warm cabin air. His argument contemplated a difference in temperature between skin and stringer of as much as 60 deg. or 70 deg. Cent. This would have the

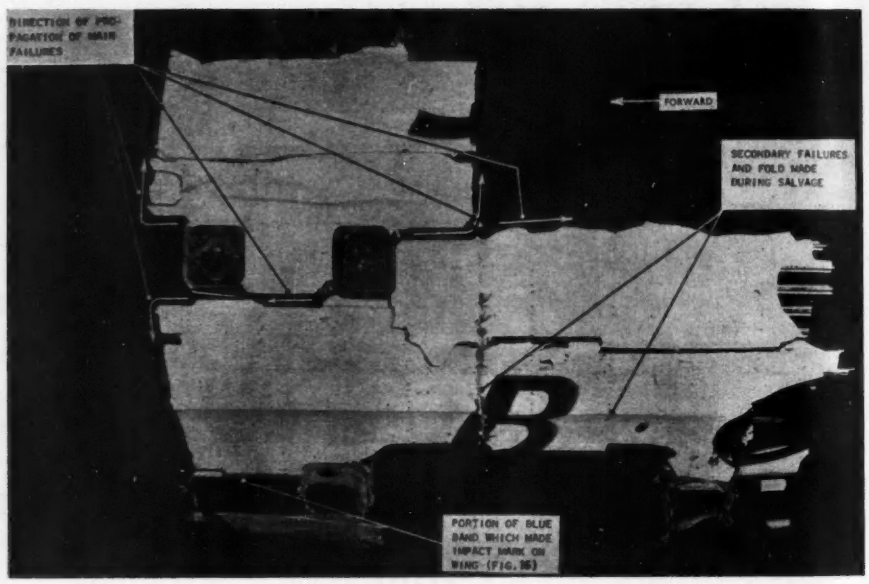

DIRECTION OF PROPAGATION OF MAIN FAILURES
FORWARD
SECONDARY FAILURES AND FOLD MADE DURING SALVAGE
PORTION OF BLUE BAND WHICH MADE IMPACT MARK ON WING (FIG. 36)

Fig. 5—Wreckage around A.D.F. aerial windows. G-ALYP

* Published C.A.P. 127, Ministry of Transport and Civil Aviation. Price 8s.

† Fig. 5 includes two other pieces recovered earlier.

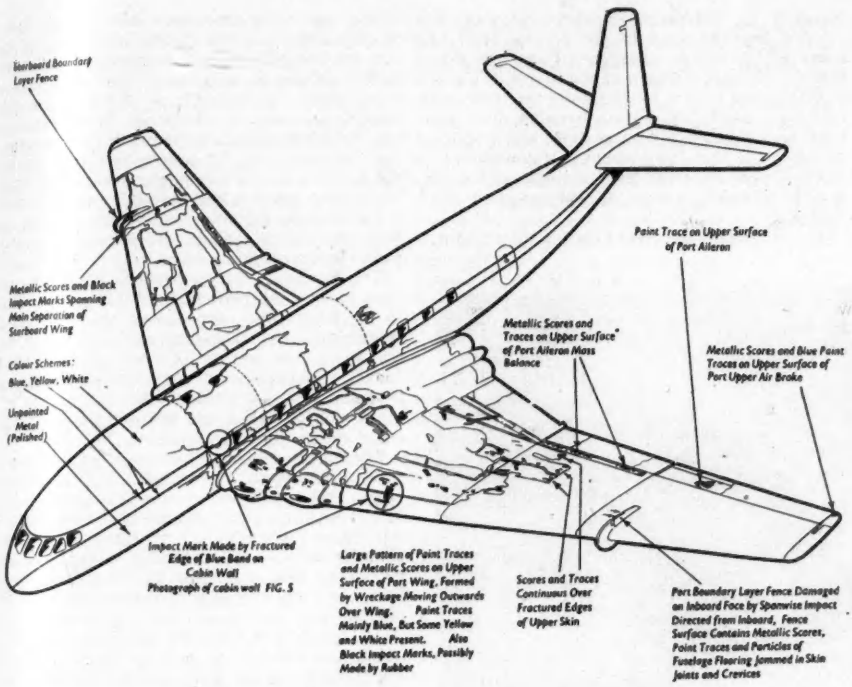

Starboard Boundary Layer Fence
Metallic Scores and Black Impact Marks Spanning Main Separation of Starboard Wing
Colour Schemes: Blue, Yellow, White
Unpainted Metal (Polished)
Impact Mark Made by Fractured Edge of Blue Band on Cabin Wall
Photograph of cabin wall FIG. 5
Large Pattern of Paint Traces and Metallic Scores on Upper Surface of Port Wing, Formed by Wreckage Moving Outwards Over Wing. Paint Traces Mainly Blue, But Some Yellow and White Present. Also Black Impact Marks, Possibly Made by Rubber
Scores and Traces Continuous Over Fractured Edges of Upper Skin
Metallic Scores and Traces on Upper Surface of Port Aileron Mass Balance
Paint Trace on Upper Surface of Port Aileron
Metallic Scores and Blue Paint Traces on Upper Surface of Port Upper Air Brake
Port Boundary Layer Fence Damaged on Inboard Face by Spanwise Impact Directed from Inboard, Fence Surface Contains Metallic Scores, Paint Traces and Particles of Fuselage Flooring Jammed in Skin Joints and Crevices

Fig. 6—Impact damage to upper surfaces of wings. G-ALYP

result that the skin would contract relative to the stringer, in the direction of the cabin's length. The adhesive would, therefore, be subjected to a shear stress which might be sufficient to cause it to fail.

(*b*) Even if this did not cause the adhesive to fail statically (that is, on the first occasion when such a difference of temperature between the skin and the stringers occurred) frequent repetition of the shear stress might produce fatigue in the adhesive, and cause it to fail.

(*c*) Mr. Jablonsky recognised that the dependence on temperature level of the properties of "Redux" is well known. He suggested, however, that frequent and rapid variations of temperature would reduce its strength substantially.

(*d*) It is generally recognised that the satisfactory use in engineering structures of any form of adhesive (or, indeed, of processes essentially similar, such as the welding or soldering of metals) can be ensured only by the development and maintenance of higher standards of workmanship and process inspection than are necessary in the use of riveting. While Mr. Jablonsky recognised that de Havilland's production technique for "Redux" had been developed after many years' study of its properties, and that their experience of its use in other aircraft had been highly satisfactory, he suggested that it was not a process sufficiently reliable for use in the primary structure of a pressure cabin.

Mr. Jablonsky said in evidence that in his inspection of the wreckage at R.A.E. he had seen examples of failure of the "glue line" which had satisfied him that weakness in it was primarily responsible for the failure of the structure of the cabin.

I deal below with these points separately :

(*a*) During the experiments made in flight on "Comet" G-ANAV at R.A.E., measurements were made of the difference in temperature between the skin and the stringers in typical positions in steady flight at cruising altitude. They led to the conclusion that the maximum probable steady difference in temperature is about 10 deg. Cent. I am advised that the shear stress in the "Redux" caused by the relative contraction between the skin and the stringers due to a temperature difference of this order would be well within its capacity.

Mr. Jablonsky did not agree that any reliable inference about the conditions on an operational climb could be drawn from these experiments. I recognise that this comment has some force, but I base my conclusions on this aspect of his criticism on the more general considerations set out in paragraphs below.

(*b*) No evidence was submitted of the effect, on the fatigue strength of a "Redux" joint, of the level of temperature of the adhesive. But I am advised that the wide experience of its use by de Havilland's in the structures of other aircraft, where alternations of load on the glue line have certainly existed in numbers far in excess of any likely to have been experienced in the cabin structure of the "Comet," and over a wide range of temperature of the "Redux" itself, a satisfactory evidence that this is not a probable cause of failure of the "Redux" joints in the "Comet's" cabin.

(*c*) de Havilland's made special tests to investigate the effect on typical joints of repeated alternation of temperature between 60 deg. Cent. and −50 deg. Cent. I am advised that these show that alternations of temperature within this range have no appreciable effect on the strength of a "Redux" joint.

(*d*) At my request, de Havilland's submitted a statement which summarised the history and present state of their production methods in the use of "Redux," with particular reference to its application to the construction of the "Comet." Mr. Povey, the director responsible for production, gave evidence on the point. I am advised that this statement and evidence show that de Havilland's fully appreciated the importance of this aspect of the use of an adhesive in essential structural components, and that the methods they have devised, including process control and inspection, tests of samples of every joint, and periodic stripping of complete stringers from the skin, provide all the assurance that could reasonably be required.

However, the final test of a process of this type is recognised to be experience in service. No evidence was produced of any failure of de Havilland's methods of dealing with the same problem in aircraft such as the "Hornet" and the "Dove," in both of which "Redux" is widely used. Moreover, inspection of "Yoke Uncle" at R.A.E., both before and after it was tested under repeated loading, showed no signs of any deficiency in the glue line. It must be remembered that before it was delivered to R.A.E. for tests, this aircraft had done 3521 hours of flying on B.O.A.C. services, experiencing the conditions of temperature, and of temperature variation between the skin and the stringers, contemplated by Mr. Jablonsky.

Finally, examination of the wreckage led Mr. Ripley to conclusions, contrary to those inferred by Mr. Jablonsky, for reasons which he explained in detail.

It has been established to my satisfaction that the rear part of the fuselage, substantially intact, hit the surface of the sea at high speed, open end downwards. This caused the equivalent of an explosion in it, whose effects were naturally most acute near the open end. I am advised that the failure, under these circumstances, of the adhesion between the skin and the stringers cannot be regarded as evidence of the failure of the adhesive to meet the requirements of the normal use of the aircraft. There was in this neighbourhood abundant evidence of the failure of all the methods of attaching the various structural components to one another. Moreover, the numerous places where the skin had parted from the stringers exposed the glue line to examination, and Mr. Ripley said that he had been unable to find any sign of any unsatisfactory features in the process employed by de Havilland's, or of any weakness in the adhesive.

In the light of these considerations, I have no hesitation in rejecting Mr. Jablonsky's suggested alternative cause of the failure of the cabin.

Mr. Tye's Evidence.—The only other witness who did not completely accept the suggestion advanced in the report was Mr. Tye. He did not dispute that the primary cause of the accident was the bursting of the cabin structure, but he expressed himself as not entirely satisfied that fatigue was the cause of that disruption. He appears to have proceeded on the basis that the 9000 hours (3000 flights) at which "Yoke Uncle" burst could be regarded as a fair average life for the fuselage and to have been impressed by the improbability, on this basis, of both "Yoke Peter" and "Yoke Yoke" failing from fatigue after only about 3000 hours (1000 flights). He was unable, however, to suggest any other cause.

Certain Defects Referred to in the R.A.E. Report.—I turn now to the other defects dis-

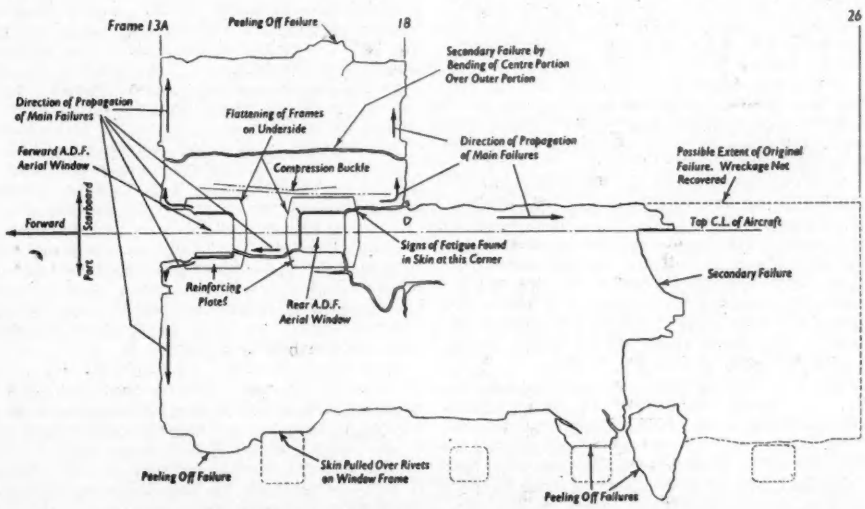


Fig. 7—Salient features of disruption of pressure cabin. G-ALYP

covered by R.A.E. and already referred to. I see no reason to differ from the conclusion reached by R.A.E. that none of these defects was in any way the cause of the accident.

It is clear that the separation of both port and starboard outer wings from the centre section (see Fig. 4 *ante*) was not the primary cause of the accident, for there is ample evidence from the distribution of paint marks and scratches on both wings that they were made by parts of the cabin structure, and form a pattern (see Fig. 6) which is consistent only with the whole wing having been intact when they were made. For the same reason, the known point of fatigue weakness in the wing skin near the edge of the wheel wells is not suspect. Moreover, the fracture of the wings occurred some distance outside this region.

[The other defects were then discussed.]

Responsibility

No suggestion was made that any party wilfully disregarded any point which ought to have been considered or wilfully took unnecessary risks.

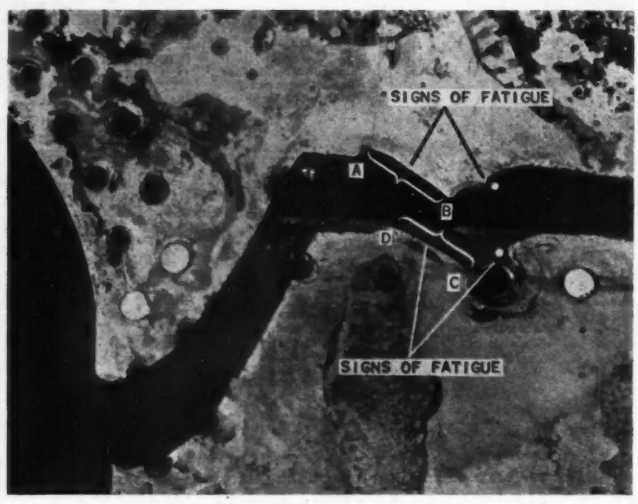
Criticism of de Havilland's Design Work.—Dealing first with the period prior to the commencement of the scheduled passenger service on May 2, 1952, the calculations made by de Havillands were criticised. It is, however, to be observed that the primary object of de Havillands was to lay the foundation for extensive tests which they regarded as the soundest basis for the development of a project rather than to arrive at a precise assessment of the stress distribution at the corners of the cabin windows.

I do not think that they can justly be criticised for this approach to the problem. In arriving at this conclusion I have been assisted by a Memorandum (below) which has been prepared for me by my assessors and which confirms the impression I formed from the evidence of the witnesses that de Havillands were proceeding in accordance with what was then regarded as good engineering practice. I am also satisfied that in the then state of knowledge de Havillands cannot be blamed for not making greater use of strain gauges than they actually did or for believing that the static test that they proposed to apply would, if successful, give the necessary assurance against the risk of fatigue during the working life of the aircraft.

Memorandum by Assessors.—During the design of the " Comet " de Havillands did not make use of calculations in an attempt to arrive at a close estimate of the stress distribution near the corners of the cabin windows. We have examined such of their calculations as had a bearing on this question ; these led to the stress of 28,000 lb per square inch mentioned by Mr. Harper. It is clear that this stress refers to an area of the skin in the neighbourhood of the corners, and may fairly be said to be an average value over a width of 2in or 3in. de Havillands believed that their method was satisfactory for the purpose they had in mind, namely, the design of a test specimen. They did not consider that a closer estimate of the highest value of the stress could be made by any method which they would regard as reliable. They preferred to rely on tests of specimens designed on the basis of their calculations.

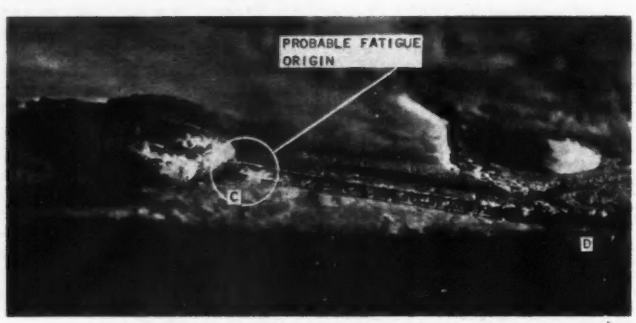
Since their estimate of the general level of stress in the region investigated was less than half the ultimate strength of the material (about 65,000 lb per square inch) they were confident that they could demonstrate by static test that there would be no failure at twice the working pressure, and that there would be a considerable reserve in hand. Their tests of panels about 3ft square, including a window, substantiated this view.

We note, however, that in these tests the panel was supported on the face of a stiff steel "pressure box," and not in conditions truly representative of those which existed near the window in the pressure cabin itself. It is not possible to say what the effect of this would be. de Havillands were reassured by the results of the tests, in which the specimen withstood nearly 20 lb per square inch without failure.



Plan view of failure in skin.

Fig. 8 (a)—Signs of fatigue in skin at starboard rear corner of A.D.F. aerial window. G-ALYP



View of edge *C—D*.

Fig. 8 (b)—Signs of fatigue in skin at starboard rear corner of rear A.D.F. aerial window. G-ALYP

de Havillands used the same approach to the design of the whole pressure cabin. The static tests which they made on the two parts of the pressure cabin, respectively 26ft and 24ft long, gave them confidence in the integrity of the whole cabin. Since they believed, with general support from then current practice and opinion, including that of A.R.B., that this basis of design and static tests would give ample assurance against risk of failure under repeated applications of the working pressure, and other known causes of fatigue, they felt that the cabin was good for the life of the aircraft (say, 10,000 pressurised flights, or ten years).

Here again, however, we note that the test sections of the cabin differed from the cabin as fitted to the aircraft in several respects. In the first place, each was incomplete, and incapable of sustaining pressure if it had not been fitted with a stiff bulkhead at the open end or ends. It is not possible to say whether the constraint which these bulkheads imposed on the structure would make it stronger or weaker than when it formed part of a complete cabin. But it must be recognised that the stresses in the structure near the bulkheads would be appreciably affected by the constraint, and the reliability of deductions about the strength of the cabin would thereby be reduced. Secondly, neither section was fitted with the complete number of windows, &c. Moreover, the windows of special interest in this Inquiry, which were in the front test section, were rather near the bulkhead mentioned, so that the stresses in the skin round them might have been appreciably different from those in similar places in the complete cabin.

The increasing attention which de Havillands gave, during the period mid 1952 to end 1953, to the fatigue life of pressure cabins has been mentioned. In their repeated loading tests the front test section of the cabin survived 16,000 applications of just over the working pressure. They felt confident that the " Comet's " cabin would have a safe life well beyond their target of ten years in service.

The repeated loading test on " Yoke Uncle " at R.A.E. led to an unexpected failure after some 3000 applications of load. Though this was about three times the life of " Yoke Peter" at Elba or " Yoke Yoke " at Naples it was surprisingly short, and led directly to the inference that there were high local stresses. Steps were therefore taken at R.A.E. to measure the stresses near the corner of the window, using strain gauges placed as near as possible to the edge of the skin where the failure started. These measurements led to an estimated stress of 43,000 lb per square inch at the edge at the normal pressure difference of 8¼ lb per square inch.

This estimate of the stress was regarded by de Havillands as unreliable, partly because the process of deriving it from the experimental measurements involved some extrapolation, but also because it would imply that in their own test to twice the working pressure there was a local stress of double this amount, namely, 86,000 lb per square inch, which is some 30 per cent above the ultimate strength of the material. This apparent paradox can be explained by recognising that it neglects to take account of the effect of the ductility of the material in relieving " stress concentrations."

Calculations were made by Sir Arnold Hall to explore the problem in the light of such theoretical solutions as were known of the problem of stress distribution, round a cut-out of the shape of the cabin windows, in a cylindrical shell of metal under pressure. These calculations were not put forward as exact, but, with due allowance for the fact that the window frame, and the cabin stringers and hoop frames, would influence the result, they supported the reasonableness of the estimate made from measurements on " Yoke Uncle."

It is our view that the two results taken together point strongly to the conclusion that the stress in the skin at the edge of the window near the corner was far higher than had been suspected by de Havillands, and was probably over 40,000 lb per square inch under the normal pressure difference.

In the course of the inquiry much attention was paid to an estimate on the tests on " Yoke Uncle " of the stress which might be predicted on the basis of their measurements by strain gauges, as probably existing in flight. The figure " 70 per cent of the ultimate strength " was obtained by adding to the 43,000 lb per square inch (mentioned above) due to the working pressure, another 2700 lb per square inch due to other known loads, leading to a total of 45,700 lb per square inch. This was contrasted with de Havilland's own estimate of 28,000 lb per square inch. It has already been pointed out that de Havillands' figure relates to an average over a considerable distance near the corner of the window, and due only to the working pressure, whereas the estimate made by R.A.E. relates to a particular point where the stress would be expected, on general grounds, to reach a maximum. A direct comparison between them is therefore misleading. Having regard to the different approach the two figures cannot be said to be inconsistent.

Criticism of de Havillands' Repeated Loading Tests in 1953.—Another criticism of de Havillands was connected with the repeated loading tests carried out by them in 1953. When the

R.A.E. test revealed the short life of the cabin structure of "Yoke Uncle" the question arose as to how to reconcile the result of that test with the result of these earlier repeated loading tests. Sir Arnold Hall suggested that the explanation might well be that the 1953 tests were carried out on a nose section which had previously been subjected to static tests up to a differential pressure of 16½ lb per square inch and that the effect of such a test might be to prolong the life of the specimen subjected to it. Mr. Harper said that he was aware of this possibility, but he considered that if there was any increase in life of the nose section attributable to preloading the tests so amply covered the life of the aircraft both at the time of the tests and for the immediate future that de Havillands could safely accept the test as satisfactory. In the then state of knowledge I think this conclusion was reasonable.

de Havillands' Method of Dealing with Cracks.—There is one other question bearing on responsibility to which I must refer. This concerns certain cracks, revealed by the examination of the wreckage, which had occurred in the process of manufacture and had been dealt with by location. Sir Arnold Hall said that such manufacturing cracks might form foci for fatigue and thus shorten the life of the structure. It was suggested in cross-examination that the fatigue which led to the disintegration of "Yoke Peter" had originated in these cracks, that they ought not to have been dealt with as they were and that accordingly some responsibility ought to attach to de Havillands for allowing the aircraft which contained them to be put into service.

The methods employed by de Havillands in dealing with manufacturing cracks were in no way different from those used to deal with other deviations from the strict requirements of the drawings to which the aircraft was being built. Defects, whether discovered by the workman or the inspector, would be dealt with by the procedure known as "Concession," procedure which varied according to whether the defect was classed as major or minor. Mr. Povey said that manufacturing cracks were required to be dealt with as major defects with the result that "Concession Notes" containing the proposals for dealing with them would have to go forward to the Chief Inspector and, if approved by him, would have to be submitted to the Design Department for final approval. In the case of "Yoke Peter" three cracks were discovered in the reinforcing plates of the A.D.F. windows. The action taken, which was approved by the Chief Inspector and the Design Department, was "splits have been located with a 1/16 diameter drill hole." According to the then current engineering practice, this action would have been appropriate had the stresses been as low as de Havillands believed them to be, but was, in fact, inappropriate as the region concerned was one in which there were high stresses. However, as I have already stated, my opinion that de Havillands cannot be blamed for their ignorance of the true state of affairs, it follows that no responsibility attaches to them.

The evidence disclosed other cracks in "Comet" aircraft. Thus in the wreckage of "Yoke Peter" there was a crack in the skin at the starboard front corner of the rear A.D.F. window. This had been located at both ends. No "Concession Note" was available in relation to this crack and it would appear that there had been a defect in the operation of the Concession procedure. Although this crack had spread during the life of the aircraft beyond one of the points at which it had been located, the actual fracture did not take place there nor was there any sign of fatigue. Other cracks were referred to in "Yoke Uncle" and "Yoke Yoke," but in no case was there any evidence that the crack had contributed to the failure of the aircraft.

Further Suggestions Directed to Guarding Against Fatigue.—The problem of securing an economically satisfactory safe life of the pressure cabin of an aircraft needs more study, both in design and by experiment, if the lightest possible safe structure is to be achieved. This is recognised by de Havillands in their policy in regard to the future of the "Comet."

The policy which de Havillands propose to adopt for the "Comet" is directed to achieving this end, primarily by reducing both the general level of stress and the local excesses, due to all known causes, above the general level of stress. The knowledge which has been acquired as a result of the investigation of the accident to "Yoke Peter," and the tests made on "Yoke Uncle" at R.A.E., strongly suggests that steps should be taken to determine by calculation, by tests of typical parts of the cabin, and by tests on one or more complete cabins, both the distribution of stress throughout the structure in considerable detail, the influences which determine both the highest static load which it will sustain, and its life to failure under repeated loading. In the present state of knowledge it is likely that two complete cabins will have to be tested, one under static loads and one under cycles of repeated loads.

From the evidence of Sir Arnold Hall and from advice I have received from my assessors it became clear that there exist methods of calculating the stress distribution in the structure of a pressure cabin which could with advantage be employed more widely. Moreover, the result of R.A.E.'s investigation satisfied me that in tests of pressure cabins or parts of them the stress distribution should be determined by wide use of strain gauges. This procedure will enable the calculations used in the design to be verified or amended, and will lead to a fuller understanding of the problem.

Use of Available Government Facilities.—It is essential that in the future manufacturers should be aware of, and should make full use of, such facilities as the research establishments of the Ministry of Supply can offer. The Court was informed that in practice there had been close personal association between members of the staffs of A.R.B. and R.A.E. and that R.A.E. was represented on the Airworthiness Requirements Co-ordinating Committee of A.R.B. It is desirable, nonetheless, to strengthen the liaison between A.R.B. and all the research establishments of the Ministry of Supply and it might be worth considering whether, when the Council of A.R.B. is being strengthened in accordance with the statement made by Sir Lionel Heald, it should not also receive such additional reinforcement as will encourage the full use by manufacturers, operators and A.R.B of all available facilities.

Suggested Scientific and Technical Investigations.—There are certain scientific and technical matters on which, acting on the advice of my assessors, I recommend that research can usefully be undertaken. The first arises from the influence of the ductility of the aluminium alloy from which the skin of the cabin is made, on the manner in which the stress distribution in the skin is related to the difference between the internal and external pressure on the cabin.

As the pressure difference in the cabin rises from P to, say, 1½ P the stresses everywhere will rise in the same proportion. But as the pressure difference approaches, say, 2 P the stress in the more highly stressed regions will reach that at which the material is no longer elastic. Its extension will then be of a plastic nature, that is to say, one which does not disappear when the stress which caused it is removed. Over most of the skin the stress will remain within the range in which the material is still elastic and the removal of the pressure will restore this part of the skin to its original dimensions. But in areas where the stress was high there will remain a permanent stretch. The preloaded cabin is therefore physically different from a new one, if the preload has exceeded a certain level.

Although the permanent extension of the material in the areas where it has stretched plastically, but without fracture, is small and undetectable by visual inspection, it may have a profound effect on the distribution of stress in the material when the working pressure is applied a second time. Without going into details, the general nature of this will be to reduce markedly the stress in the areas where it was previously greatest. The stress concentration in such areas is therefore relieved.

This is a process whose general nature is understood, and there are examples where it has been deliberately used in order to improve resistance to fatigue. It has indeed been suggested that it might be used in such structures as a pressure cabin. But there are obvious difficulties, not to say dangers, in applying it. Nevertheless, the subject should undoubtedly receive more study, if only to ensure that tests during design are not rendered unreliable by failure to appreciate its significance.

Though there can be no direct proof, there is no doubt that the phenomenon described above provides at any rate a partial explanation of the apparent anomaly presented by the failure of the pressure cabin of "Yoke Uncle" at R.A.E. after 3000 cycles, in spite of the survival of the test specimen of the forepart of the cabin to over 16,000 cycles when tested by de Havillands. The maximum pressure difference which had ever been applied to "Yoke Uncle" was 1½ P, whereas the test specimen had been subjected to two applications of 2 P in addition to nearly twenty of between P and 2 P.

The second question which needs study may be put shortly as follows: what is the true static strength of the complete "Comet" cabin? Reasons have been given why the tests made on sections of the cabin may have been somewhat misleading. A test conducted in the tank at R.A.E., with the most comprehensive exploration of the stress distribution, would be invaluable. not only would it clear up such uncertainties as remain from our inquiry, but, in conjunction with the repeated loading tests already made on "Yoke Uncle," would provide an invaluable body of information for the basis of design of future pressure cabins.

"Redux" Adhesive in the "Comet"

IN our article "Aeronautics in 1954" (THE ENGINEER, January 7, 1955), we referred to a proposed test for pressurised aircraft where, we stated, "relatively new structural bonding techniques are used, in which certain resins are notoriously unstable at temperatures not greatly removed from those likely to be experienced." As this remark was published under a subheading "The Comet," we now appreciate that it may have been interpreted as a reflection upon "Redux," the adhesive used on a considerable scale for metal-to-metal bonding in this aircraft, and we have been informed by Aero Research, Ltd. (patentees of the process in which its "Redux" is used) that our comment is inaccurate, first because this adhesive is stable and shows no fall in strength at temperatures encountered under the conditions described; secondly, because it has been used for more than ten years in some fifty different types of machine and should not therefore be described as relatively new. We are glad to publish this correction of a comment that may have been construed as damaging and unsubstantiated as far as "Redux" is concerned. Readers will observe from the abstracts, printed above, from the Commissioner's Report of the Court of Enquiry into the accidents to two "Comet" aircraft, that "Redux" is absolved from all responsibility either as a cause or contributory cause of the accidents.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

CUSHIONING MATERIALS

No. 1133, Sec. 12, and No. 2548 : 1954. Price 5s. and 2s.—The revision of the cushioning materials section of the Packaging Code (Section 12) is considerably extended as compared with the 1943 edition and describes cushioning materials in the form of cellular rubber, cellulose wadding, cotton waste, cork, corrugated and embossed papers, fibreboard, moulded pulp, paper shavings, plastics, rubberised hair and wood wool; reference is also made to miscellaneous cushioning materials. Methods of suspension packing with springs are described, and the factors to be considered in selecting a suitable material for a particular pack are very fully discussed.

At the same time, a detailed specification for wood wool for general packaging purposes has been published as B.S. 2548. This specifies the dimensions, pH value, moisture content and other essential requirements of the materials, and it also gives methods of test.

The standard is confined to those wood wools most commonly used for general packaging purposes, e.g. for the packaging of machinery, engineering equipment, furniture, glassware and ceramics. This standard should be read in conjunction with the cushioning material section of the Packaging Code, which gives guidance on the use of the material.

Small Frequency-Stabilised Power Plant

A MOTOR alternator set for supplying electricity at a more stable frequency than is available from normal sources has been designed and manufactured by Walter Jones and Co. (Engineers), Ltd., of Sydenham, London. Typical applications for which this set is suitable include the supervisory equipment of certain chemical and metallurgical processes, radar and gyro apparatus and telegraph apparatus operated by synchronous motors.

The motor alternator set consists of a motor which is designed to deliver its full load under extreme conditions of frequency and voltage variation of the available supply and an alternator which is designed to give the specified frequency. The alternator is either a self-regulating machine or one having a separate exciter and automatic voltage regulator. The motor and the alternator are coupled through a variable ratio gear, the ratio of which is changed in accordance with the error of the alternator frequency in such a way that, with an increase in the alternator frequency, the error operates to reduce the speed of transmission of the variable ratio gear.

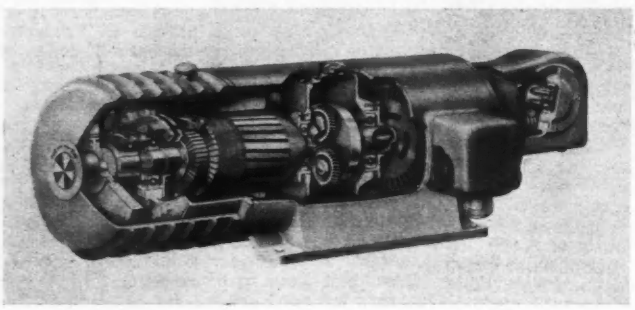


Fig. 1—Composite machine in which the speed of a synchronous slave motor is compared with that of a standard speed motor, by means of a differential comparator

The principle of operation is to compare the alternator output frequency (in terms of speed) with a standard which is described below. This comparison is made in a Walter Jones machine (Fig. 1), comprising three parts : the first is a self-excited synchronous a.c. motor which produces a rotation in step with the generated frequency of the main alternator ; the second is a constant-speed standard, and these two speeds are compared in the third part, which is a differential gear situated between the other two units with an output shaft which passes through the hollow shaft of the synchronous slave motor.

The speed standard is an accurately constructed d.c. governed motor which operates from a rectified a.c. supply. Its standard of reference results from the centrifugal and gravitational forces acting on a cantilever spring fixed near the outer periphery of the governor disc, seen on the left of Fig. 1. One contact, situated at the free end of the spring, closes with another contact fitted to the governor disc itself. The latter contact is adjustable in its radius of rotation by a fine thread screw and scale, and constitutes the means of setting the speed calibration. The resultant of the centrifugal and gravitational forces acting on the spring throughout one revolution ensures the closure of the contacts once per revolution, whilst the governor is controlling the machine speed. Beyond this range the contacts are opened for the whole time when the speed is approaching the lower limit, and closed for the whole time as it approaches the higher speed limit. The control between these two limits is thus infinitely fine, as in the Tyrrell voltage regulator. A simple amplifier (in which the contacts of the governor control the grid potential of a beam tetrode valve, supplying the motor field current) adjusts its magnitude to maintain the speed accuracy despite changes of load, temperature and input voltage. The governor has a very low temperature coefficient. It is, nevertheless, usual to set the speed 0·15 per cent fast when the machine is cold, in order to be correct at the final operating temperature of the totally-enclosed governed machine. The contacts are of precious metal and, as they control a current of only 1mA, their life is very long.

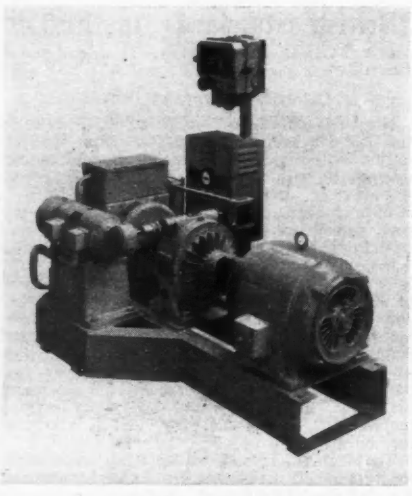


Fig. 2—Motor alternator set giving an output of 4kVA, 415V, 50 c/s with a steady-state error of ±0·1 per cent

The variable ratio gear used is the Kopp gear, in which the gear ratio is modified by the tilting of the axis of rotation of a series of concentrically arranged hardened steel spheres, against which the driving and the driven thrust plates press with a pressure which bears a definite relation to the load.

This constant rotation is used as a speed/frequency standard, accurate to approximately plus or minus one part in a thousand for very long periods without attention. The available output from these two motors (the speed standard and the slave motor) when they are running at different speeds is such that the excess torque is sufficient to operate a ratio changing shaft of the variable ratio gear via a worm reduction gear. In the steady-state operation of a plant of this kind, the speed of the alternator and the speed of the standard machine may be seen to operate in synchronism when both are viewed through a stroboscope.

The set is designed to compensate for an input frequency change of up to 1 c/s per minute with a 50 c/s supply, which is believed to be more than double the fastest rate of frequency change likely to be encountered.

Another transient condition to be considered is that resulting from sudden load changes. When the driving motor is of the asynchronous induction type, sudden load change causes a sudden change of slip, which has to be corrected by the automatic correction equipment. To restore complete correction requires approximately twenty seconds, but about 80 per cent of the correction occurs in ten seconds. This use of induction motor drives is restricted to cases where sudden load changes of not more than about 15 per cent of the output power occur. In cases where a large proportion of the output power has to be switched on and off, synchronous induction motor drives are used, and the automatic frequency control has then to correct for input frequency errors only.

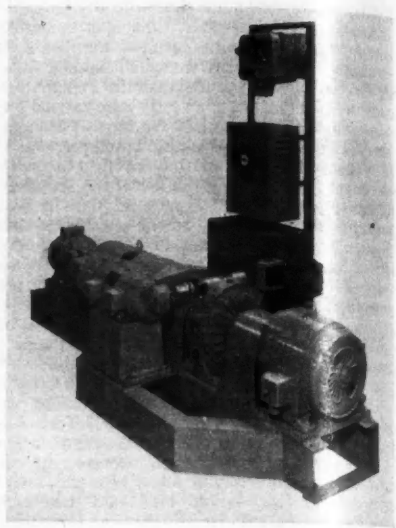


Fig. 3—Motor alternator set giving an output of 2kVA, 115V, 400 c/s with a steady-state error of ±0·1 per cent

The set illustrated in Fig. 2 gives an output of 4kVA, 415V, 50 c/s, with a steady state error of plus/minus one part in a thousand from a 50 c/s, 415V supply, the frequency of which varies ±10 per cent, and the voltage by ±15 per cent. The motor is an induction motor and the alternator a self-regulating machine, giving voltage accuracy of ±3 per cent full-load to no-load. The set illustrated in Fig. 3 accepts 415V, three-phase, 50 c/s and gives a stabilised output of 115V, three-phase, 400 c/s, 2kVA, with frequency correct to plus or minus one part in a thousand, during steady state operation. The control panel shown in Fig. 3 contains the star-delta starter for the induction motor, the field circuit amplifier of the standard motor and below, the electronic voltage regulator for the 400 c/s alternator.

In the conversion of a variable 50 c/s supply to a constant 60 c/s supply, and where the output voltage can be a substantially fixed ratio, compared with the input voltage, the frequency conversion takes place in a frequency converter constructed in the same way as a wound rotor induction motor, where the rotor is driven through the variable speed gear at the difference speed, for example, 600 r.p.m. in the case of a two-pole frequency converter.

The frequency comparator device, shown in Fig. 1, can also be used to effect control of gear units transmitting up to 100 h.p., or it may be used to operate other control devices, such as variable resistances, variable ratio transformers, or the fuel supply to prime movers.

MODERN LOCOMOTIVE SHEDS.—After sixty years' service, it was decided in 1952 that the roofs of the British Railways North Eastern Region motive power depots at Ardsley, Wakefield, Sunderland, Sowerby Bridge, Bowes Bridge, and Goole must be renewed. This work was completed during 1954 to a standard form of construction, bearing in mind that the sheds may be used for locomotives other than steam at a later date. A clear height of 21ft from the rail level to the roof is provided, with 18ft headroom from rail level to beam soffits over tracks. The main beams, spanning a maximum of four tracks within the sheds, are of post-stressed, precast concrete, supported by brick walls on reinforced concrete columns spaced longitudinally at 24ft standard centres. Longitudinal secondary pre-stressed beams of channel section are placed in pairs and they carry the roof cladding, smoke ducts, and walkway slabs, and also act as rainwater gutters. Two standard cross-sections were adopted for the main beams.

Some Current Aeronautical Research*

By SIR ARNOLD HALL, F.R.S.†

Some abstracts are reproduced herewith from a paper entitled "The Influence on Civil Aviation of Some Current Researches." It began with a discussion of some economic aspects in the operation of high subsonic and supersonic transport aircraft. Sections on the likely influence of different forms of boundary layer control, either to reduce the viscous drag or decrease the landing speed and on some recent findings about metal fatigue, are given below. The paper concluded with sections on aircraft noise, blind flying aids and techniques and fog dispersal equipment.

Take-off and Landing Characteristics

Were it not for the possibilities with which I will deal briefly in this section, the trend of the past towards increased take-off and landing distance, and increased approach speed on landing might continue in the future if maximum economy in the cruising phase were demanded. It is, of course, popular to criticise the runway—particularly when it gets longer—but the fact is that, for civil aviation, the runway is by no means a bad or expensive way of taking to the air and returning to the ground, and length of runway is one of the best bad weather landing aids that can be had. On economic arguments, it would be folly to penalise the efficiency of the aircraft as a flying machine in order to save a little on airport costs. The costs of runways, in terms of money and land, should be considered against a wider background than the critics are sometimes willing to admit. It may be true that there is enough concrete in London Airport to make a road from London to Glasgow, but since this facility forges a vital transport link not just between two cities a few hundred miles apart, but between cities all over the world, is this really too high a price to pay ? The civil engineering requirements of civil aviation look far less monstrous if they are considered side by side with the corresponding needs of, say, a railway system. A hundred years ago our predecessors threw across this country the present network of railway lines ; let the critics of runways consider what that feat involved in terms of land, tunnelling, embankments and bridges.

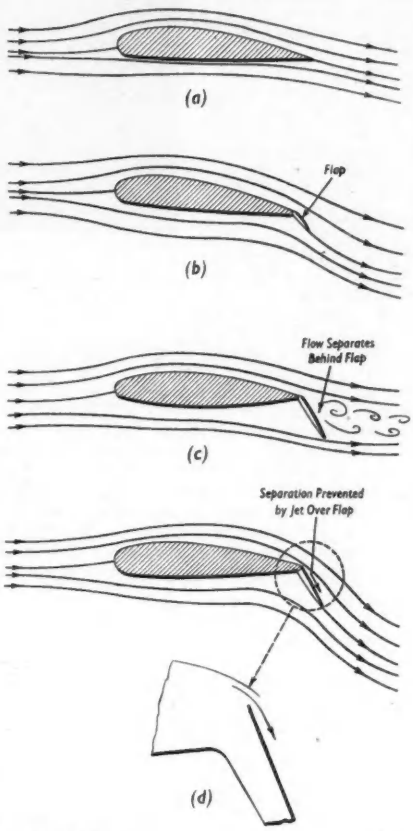
The problem of getting more lift for aeroplanes, so that their approach, landing and take-off speeds can be reduced can therefore be approached in two ways—or by a combination of both. The wing itself might be made to throw sufficient air downwards at a lower forward speed or the lift given by the wing at the landing and take-off phase might be augmented, or even replaced, by lift provided by a downward "jet" generated by machinery.

If this is achieved, in one way or another, another problem must also be solved, and that is the provision of adequate control at the lower flying speeds obtained. The normal elevator and aileron controls depend, for their effectiveness, on the forward speed of the machine—just as does the wing in producing its lift—and as this speed is reduced so they become the more ineffective. Therefore, if advantage is to be taken of any reduction of flying speed obtained, conventional controls must either be made more effective or be replaced, wholly or partially, by other means.

The conventional way of getting more lift from a wing is to put down a flap at the trailing edge. The limit to what can be done this way is reached when the air flow "breaks away" from the surface (Fig. 1). It has been known for a long time that if air is blown over the flap this breakaway can be delayed, and more lift therefore obtained. In a turbo-propelled aircraft it is likely to become possible to provide large volumes of air by tapping the propulsion engine compressors at relatively small cost in weight. The specific weight of jet engines is now such that the provision of a small engine as a gas generator, for this duty alone, can at least be contemplated. Initial work based on this idea is promising.

If the amount of air so blown is increased it begins to make a significant contribution to lift by virtue of its own momentum—not only does it increase the "downward jet" created by the wing, but it becomes a significant additional downward jet itself, and a system emerges which is midway between the "augment-the-wing" and the "machine generated jet lift" concepts.

"Machine generated jet lifts" can be provided in two forms, in the extreme by the installation of engines for the sole purpose of creating downward jets or by deflecting in a downward direction the jets of the main propulsion engines.



(*a*) Straight wing.
(*b*) Influence of flap.
(*c*) Limit of influence of flap caused by separation of flow.
(*d*) Effectiveness of flap restored by jet which prevents separation.

Fig. 1—Effect of flap on flow around wing

The experimental device which has become known as the "Flying Bedstead" is an example of an aircraft wholly sustained by machine-generated lift. The purpose of this device is not to demonstrate that its two "Nene" turbo-jet engines can lift it ; that much is clear from simple calculation. Its purpose is to make experiments on the control of a machine by small jets of air, which, in the "Bedstead," are fed from the main engines through a suitable control system operated by the pilot. The stability and ease of control achieved are evidence that such a system of control is entirely practicable. Such direct lift, so controlled, can, in principle, be used to reduce the lift required from the wing, so reducing the minimum flying speed of the aircraft. In the extreme case it could reduce the distribution needed from the wing to zero, so that the aircraft can land and take-off vertically.

[A "Meteor" aircraft which has been converted for experimental use in investigating the downward deflection of the main propulsive jets was shown on a slide.] Plainly, this type of installation can produce useful effects only if the thrust of the propulsion engines is a substantial fraction of the weight of the aeroplane, a condition to be found in military, rather than civil, aircraft. However, it illustrates another facet of the "machine-generated lift" concept. In this aircraft the propulsive jets can be deflected 60 deg. downwards, and the aircraft is capable of a stable minimum flying speed which is more than 20 knots lower than the standard type.

It will be evident that the key to the practical application of these ideas is the availability of engines which are very light in weight in relation to the thrust they are capable of providing. We are now entering the stage of development of turbine engines when the gathering of these fruits of lightness can at least be contemplated. It will turn out, as usual, that the advantages can be taken either in terms of reduced approach and landing speed, or in terms of cruising economies, or a combination of both. I return to my plea that, in civil aviation, we should use such advances to ensure the safety and reliability of the landing operation before going too far in gathering advantages of other kinds.

Resistance to Motion : Can it be Reduced ?

In recent years we have learned much about the stability of laminar boundary layers (see Fig. 2), and

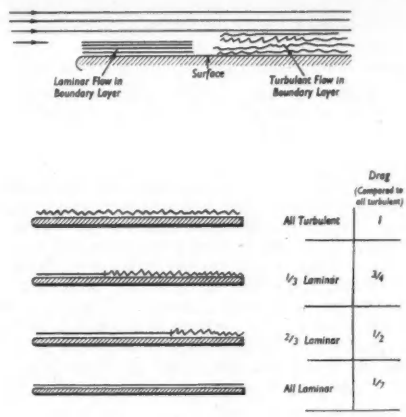
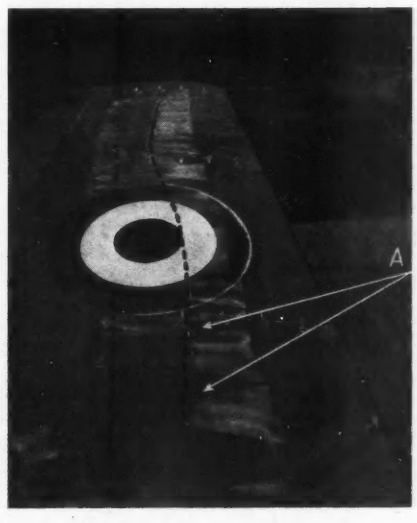


Fig. 2—Effect of state of boundary layer on skin friction

on the conditions which must be met if transition to the turbulent state is to be prevented, and what had emerged by two or three years ago was that, having in mind the stringent surface conditions, in terms of smoothness and absence of waviness, needed to secure "natural" laminar flow, it was most unlikely that practical application could be made unless the basic stability of the layer could be increased. Fig. 3 shows the extent of laminar flow achieved on the wing of a high-speed aircraft after close attention to surface detail, and Fig. 4 shows the deterioration which occurred after a few hours' flying, due to the roughening of the surface by rain erosion. In these pictures the white patches are areas of laminar flow, shown up by a technique we were able to devise for use in flight.

These considerations led to experiments



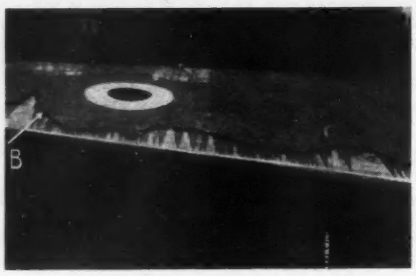
A—Typical wedge of turbulence due to surface imperfection.

Fig. 3—Laminar flow regions on wings of high-speed aircraft, showing sensitivity to surface condition

* The Brancker Memorial Lecture, Institute of Transport, February 14th.

† Director, Royal Aircraft Establishment, Farnborough, Hants.

directed towards increasing the stability of the laminar boundary layer, and of the several methods proposed, one of the more promising involved making the surface porous so that air could be sucked through it continuously from the boundary layer. Fig. 5 shows an experimental section on the wing of a "Vampire"



B—Laminar flow limit on same aeroplane after flying in rain.

Fig. 4—Laminar flow regions on wings of high-speed aircraft, showing sensitivity to surface condition

aircraft in which such a porous surface and suitable pumping equipment have been installed. We have found it possible to maintain laminar flow in flight over the whole surface by this means. This has resulted in a reduction of the effective drag of the section of wing concerned to about one-quarter of its initial value, taking account of the pumping power. Typically, the actual drag of the section is reduced to one-tenth of its initial value, while the pump power needed to achieve this result is equivalent to about one-sixth of the initial wing drag. The quantity of air which must be sucked through the surface is very small indeed; typically, the velocity through the porous surface is 3in per second. We found, however, that this result could only be maintained with careful attention to the preservation of smoothness and lack of waviness in the surface—though there are easements compared with an "unsucked" surface.

Meanwhile, a further discovery was made—and subsequently explained by theoretical argument—which showed that it is much more difficult to maintain laminar flow on a swept-back wing than on a straight wing. Meanwhile, also, the advances leading to the possibility of the long-range, high subsonic aeroplane discussed in Section 1 had steadily made it more certain that a competitive aeroplane of the next generation must cruise at speeds of the order 500 m.p.h., and that even without laminar flow, distinct economies as compared with present-day aircraft are possible.

It is always difficult to draw general conclusions on the probable influence of such an effect as "laminarisation." I have, therefore, attempted an economic analysis of the influence it might have on the specific case of civil aircraft capable of the London-New York non-stop flight, carrying 120 passengers. The datum aeroplane has a straight wing with no laminar flow, and is designed to make the London-New York journey at 500 m.p.h. The design is then varied, on the assumption that laminar flow is achieved on a substantial part of the wing—producing about 20 per cent reduction in the viscous drag of the aeroplane—and then it is achieved on the whole aircraft surface—producing about 80 per cent reduction in the viscous drag. This latter would be a most formidable design problem to achieve by suction, and the purpose of the case is to suggest the ideal upper limit of economy rather than a practical possibility. The cruising speed is maintained at 500 m.p.h. throughout the variation. As the drag is changed, the take-off and landing performance of the aircraft varies, and the design has been adjusted to bring back first the take-off, and then the landing performance of the datum machine, and, finally, both. This is achieved by an appropriate adjustment of the wing area, and by the use of "take-off only" engines where necessary. This is done because, when the viscous drag of the aeroplane is reduced, so also is the installed power needed for cruising flight, and an aircraft emerges which is under-powered, by its propulsion engines, for take-off. The results of this analysis are summarised in Table I.

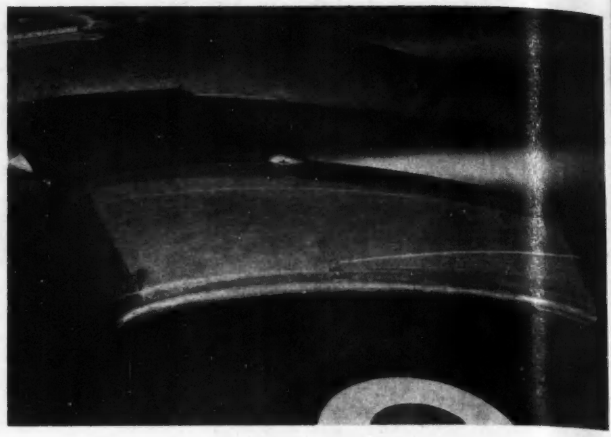


Fig. 5—Sleeve fitted with porous surface fitted to "Vampire" aircraft for experiments on reducing skin friction

I conclude that, on economic grounds, there is little to be gained from "laminarisation" of aircraft of the "London-New York non-stop" type unless much more of the surface than the wings alone is treated. Were it possible to "laminarise" the whole aeroplane's surface, a not insubstantial saving of direct cost would be gained, but I have doubts about the practicability, in engineering terms, of achieving this. Therefore, I feel that "laminarisation" of aircraft of the London-New York class is not likely to prove to be an attractive proposition. This is not to say that "laminarisation" may not find application perhaps, in ultra long-range aircraft, but its chances do not seem good for the next generation of long-range civil machines. Plainly, it will find its most effective applications where the fuel costs are a high proportion of the direct operating cost.

TABLE I

All aircraft cruise at 500 m.p.h., London-New York non-stop, carrying 120 tourist passengers.

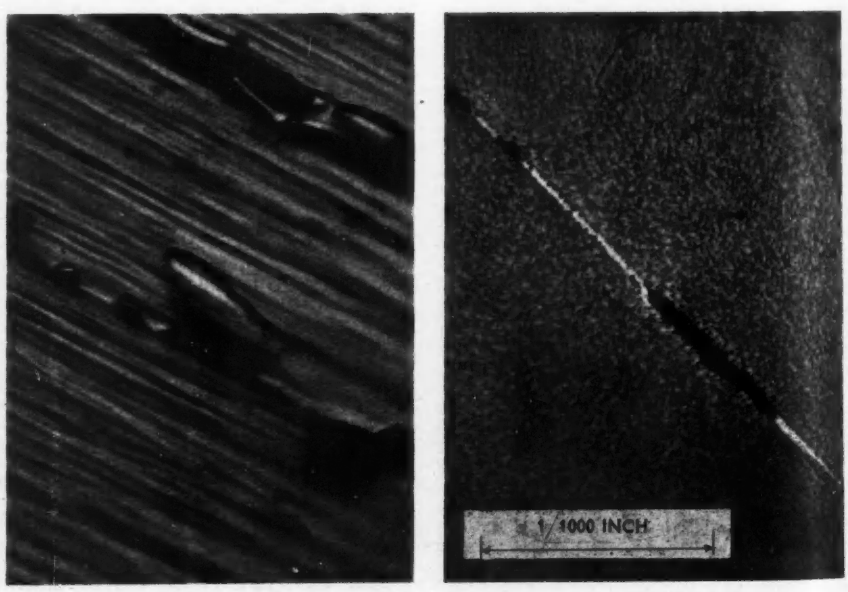
	Datum aircraft	Same take-off as datum Landing → deteriorates		Same landing as datum Take-off → deteriorates		Same take-off and landing as datum
Reduction of viscous drag	0	20 per cent	80 per cent	20 per cent	80 per cent	80 per cent
Take-off weight (lb)	228,000	215,000	158,000	230,000	162,000	170,000
Formula direct operating cost, pence per capacity long ton nautical mile	10	10	7·7	10·5	7·5	8

Note.—To obtain total operating costs, the "in practice" element, and the indirect element must be added.

THE STRUCTURAL FIELD

For civil aircraft, it is unlikely for some time to come that there will be any move away from the use of aluminium alloys for structural purposes, unless it be to the use of plastics; at supersonic speeds, up to twice the speed of sound at least, aluminium alloys will retain their attractions. If there is a competitor to aluminium for such structures as fuselages, it is glass. Glass fibre reinforced plastic is easy to form to shape on simple tools, an important consideration for civil aircraft, particularly of the larger sizes, where the total production needed will not be very large. A fuselage so formed would not be heavier than one made of aluminium alloy, would probably be cheaper, and would probably be free from the problems of fatigue, which are the main subject of this section.

Though the problems of fatigue affect all aircraft to some extent, they particularly influence the civil aircraft which flies very many more



Exudation between slip bands—aluminium, 4 per cent copper. Crack progressing along region weakened by exudation.

Fig. 6—Phenomena occurring in the fatigue process

hours than most military types and, indeed, must do so if it is to justify its high capital cost.

The fatigue properties of metallic materials used to sustain a dynamic load system are often the factors limiting the working stress level, rather than the ultimate strength of the material. Aircraft receive repeated, or oscillatory loading from, for example, encountering gusts, from landing loads, and from the rise and fall of pressure within the cabin (relative to the external pressure) during climb and descent.

In recent years we have been able to acquire a great deal of information on the distribution and intensity of gusts from counting accelerometers installed in aircraft flying all over the world. These instruments count the number of

Fig. 7—Slip band produced in aluminium by fatigue stress

times a series of levels of vertical acceleration are reached.

Recent experience has demonstrated the need, for the present at least, for exposing complete aircraft to a fatigue test, in which the mean static loads are applied to the machine, whilst the equivalent oscillatory and repeated loads are applied to the wings and pressure cabin. It is on the basis of the information acquired in the gust surveys mentioned above that we are able to apply realistic oscillatory loads, and interpret the results in terms of flying hours.

We have recently developed a gust fatigue meter to be carried in civil aircraft, which records the loadings experienced by the aircraft due to gusts, and which will act as a guide to the replacement of "fatigue worn-out" parts (particularly in the wing structure) on a basis of the actual experience of the particular machine rather than the average experience of the type, so that some maintenance economies, consistent with safety, should be possible compared with present practice.

The search for understanding of the fatigue phenomenon from a metallurgical point of view is continuously pursued in many laboratories; it is from such increased understanding that there may follow an improvement in the fatigue properties of materials, so permitting greater exploitation of the ultimate strength properties. We have made some interesting discoveries recently while working on fatigue in aluminium alloys, and this has led us to a tentative theory of the origins of fatigue which may help towards the development of alloys with improved properties.

We have vibrated small polished specimens electromagnetically and made microscopical examinations of them.

We have found that under repeated loading, within the elastic limit as ordinarily understood, slip occurs in the crystals of the material, similar to that induced when a static stress over the elastic limit causes plastic flow. Fig. 7 shows such slip bands induced by fatigue. What has occurred is that local plastic deformation is brought about by the fatigue stresses.

We have been able to observe a number of metallurgical changes taking place in the alloy before fatigue cracking occurs. One of these is the exudation of thin metallic ribbon from the crystal surfaces as shown in Fig. 6 (left). These ribbons leave a crevice in the surface which may subsequently develop catastrophically. Fig. 6 (right) shows a crack caught in the act of proceeding along such a region.

It is well-known that in aluminium alloys, high temperature promotes precipitation of the alloying atoms, and produces a soft matrix of practically pure aluminium in which are embedded large aggregates of the precipitates. One explanation of the exudation phenomenon induced by repeated loading is that the slip produced in the crystals causes local high temperatures which, in turn, cause local precipitation of the alloying atoms. The soft spots so produced are then extruded under the action of the alternating stress, and the crevice is formed, causing stress concentrations, which excite the phenomenon further, so extending the crevice which eventually becomes a fatigue crack.

If this explanation be correct, a higher fatigue resistance could result were it possible to choose alloying constituents which will not precipitate under these circumstances. Whether this will prove possible remains to be seen.

Diesel-Electric Locomotives for Sierra Leone

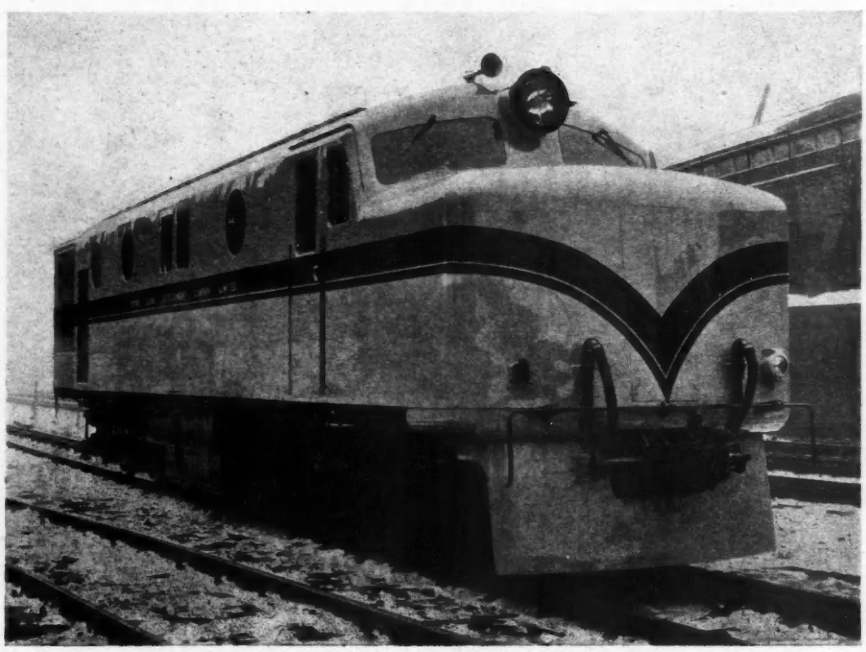
THE first of five 1000 b.h.p. AIA–AIA diesel-electric locomotives ordered by the Sierra Leone Development Company, Ltd., and built by the Birmingham Railway Carriage and Wagon Company, Ltd., in collaboration with Sulzer Brothers (London), Ltd., and Crompton Parkinson, Ltd., is illustrated on this page. These locomotives are for service on the 3ft 6in gauge line between Pepel and Marampa, a distance of some 52 miles. The railway runs from sea level to an altitude of 190ft; the maximum grade is 1·5 per cent against an empty train and 0·8 per cent against a loaded train, and the minimum radius of curvature in the main line is 819ft. A train drawn by two 1000 b.h.p. diesel locomotives will be made up of forty double-bogie ore wagons carrying 30 tons each.

The maximum permissible axle load is 13 tons and full advantage has been taken of this in order to build a locomotive with an adhesive weight of 52 tons and a starting tractive effort of 29,200 lb at 25 per cent adhesion. To obtain this adhesive weight, a certain amount of ballast has been added, as the locomotives were originally designed to weigh 61 to 63 tons and an axle load of 10¼ to 10½ tons. To reduce the non-adhesive weight to a minimum consistent with general design considerations, the idling axles, which are in the centre of each bogie, carry only 10 tons, so that an all-up weight of 72 tons is obtained. The locomotives are built for a maximum speed of 50 m.p.h., the one-hour rated tractive effort being 20,000 lb at 11·5 m.p.h., and the continuous rated tractive effort 15,500 lb at 15 m.p.h.

The six-cylinder, pressure-charged Sulzer engine develops a normal continuous output of 1000 b.h.p. at 710 r.p.m., and the continuous site rating for the new locomotives is 850 b.h.p. at 710 r.p.m. It is mounted on a common underbed with the Crompton Parkinson main and auxiliary generators. The main generator is a ten-pole machine with a continuous rating of 535kW at 710 r.p.m., 535V, 1000A, and the eight-pole auxiliary generator has a rating of 63kW at 500–710 r.p.m., 110V, 575A. The auxiliary generator is largely recessed in the main generator and their armatures are combined on a common rotor. The main/auxiliary generator is a single-bearing machine with a parallel roller bearing at the outer end. The four force-ventilated, nose-suspended traction motors are rated individually at 197 h.p., 300A, 550V one hour, and 165 h.p., 250A, 550V continuously.

An automatic load-regulation system is fitted to ensure that the engine operates at all times under favourable conditions and at the lowest rotational speed according to the load required. The driver has only one power control handle and no separate throttle handle. The control apparatus is so matched to the engine regulator that the peak tractive effort at one end of the output curve and a relatively high track speed at the other end, can each be obtained on a low controller notch. Higher notches are used for hauling heavy loads at speed or to give a high rate of acceleration. There are seventeen notches in the controller and with each notch the engine torque and speed are increased through an air-control system. In the first four notches, which are used for starting, the tractive effort also is increased in successive steps, reaching a maximum at the fifth notch.

With each notch corresponding to a fixed engine speed and torque combination, the engine



1000 h.p. AIA-AIA diesel locomotive for Sierra Leone

governor so regulates the generator and traction motor field strengths that the engine cannot be overloaded under any circumstances, even should one or more cylinders not be firing. The regulator ensures that full power corresponding to each notch is available over practically the whole locomotive speed range on that notch. This, together with automatic fuel injection timing, ensures that the specific fuel consumption over almost the whole working range is below the full-load figure.

The body framing and underframe of the locomotive are of welded steel construction and are riveted together, the weight of the equipment being taken directly by the underframe. In the all-welded bogies all the vertical loads and the traction and braking stresses are taken centrally in line with the main frame members. No springing is applied directly to the swing bolster, the complete suspension being in the form of nests of helical springs between the equalisers and the bogie frame. These springs are supplemented by shock absorbers which act only on their return strokes. Rubber springs stabilise the side movements of the swing links.

An " Integra " train control device gives the driver warning when he is approaching a signal. This device can also be used to give a special warning to the driver by the placing of a portable permanent magnet in position on the track at any suitable point. An impulse-receiving relay is secured to the bogie, and when the locomotive passes over the magnet it receives an impulse which operates a loud warning gong in the cab. This gong can be cancelled by means of a push button which the driver can hold for a short period whilst passing over the magnet to prevent the gong from sounding.

Electric Furnace for Heating Aluminium Billets

In our issue of June 11, 1954 (pages 855–856), we described a new installation for extruding an aluminium sheath on to a power cable, at the Prescot Works of British Insulated Callender's Cables, Ltd. We now give some further details, based on information received from the maker of the furnace in which the aluminium billets are heated before extrusion.

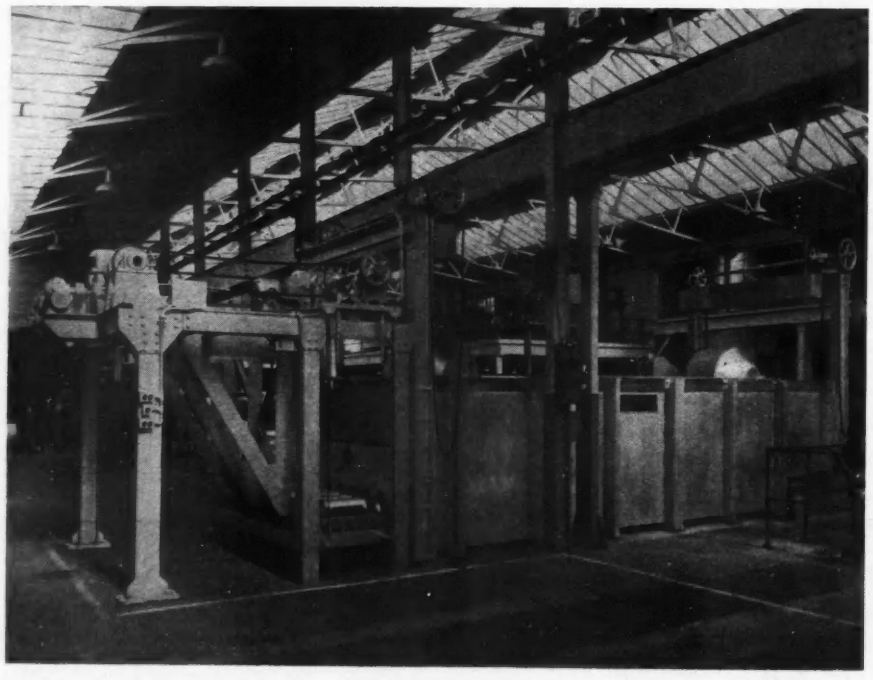
Very briefly we may recall that the extrusion of the sheath is carried out in a specially designed hydraulic press supplied by the Loewy Engineering Company, Ltd., and that the process involves the use of two billets which are charged at the two ends of the horizontal container; the billets are extruded into tube through the core and die tools positioned mid-way along the length of the container and at right angles to it. The temperature of the billets supplied to the press is critical, as there must be equal deformation of these and also complete welding in the course of extrusion, in order to obtain a satisfactory product. For sheathing direct on to some kinds of cable core the billet temperature required is of the order of 300 deg. Cent. or less, but the equipment may also be operated at temperatures up to 450 deg. Cent. for other production purposes. Accordingly, the working range required on the furnace thus extends from less than 300 deg. Cent. to a maximum of 450 deg. Cent. The furnace is an electrically heated equipment designed and installed by G.W.B. Furnaces, Ltd., Dudley, Worcs.

It has an internal chamber 20ft long by 1ft 3in high, and six rows of diabolo shaped idler rollers are fitted in the hearth. The charge varies from aluminium billets 6½in diameter by 12in long up to 9in diameter by 18in long, and the maximum output for which the unit has been designed is 1680 lb per hour at 450 deg. Cent. The total rating of 165kW is divided into two automatically controlled zones, the heating elements being spread evenly over the three-phase mains supply. Zone 1, where the initial heating of the billets takes place, is rated at 105kW, and both zones are 10ft long.

Forced air circulation is provided, as is usual at the temperature ranges involved; in this installation it is effected by two double-entry scroll fans, one of which is situated at each end of the furnace. The air is driven through the heating elements, situated in the upper portion of the furnace interior, towards the centre of the chamber, where it reverses direction and flows towards each end of the heating chamber. The nickel-chromium strip elements are suspended from removable plugs situated in the roof of the furnace, and are separated from the working chamber by insulated ducting. This ducting gives direction to the air flow, and prevents direct radiation on to the charge. For ease of maintenance the insulated covers over the fan housings are removable so that inspection of the impellers and bearings can be carried out without any difficulty. The furnace interior is lined with aluminium sprayed sheet steel and the idler rollers are of cast iron.

Since the Loewy press requires two billets for sheathing the cable, the automatic discharge mechanism of the furnace is arranged to provide two billets at a time, heated to the correct extrusion temperature. The short end sections of the idler roller rows are inclined so that the billets roll out under gravity. An electrically operated combined pusher gear and hoist is situated at the charging end of the furnace, while adjustable stops permit varying lengths of billet to be handled.

Temperature control is effected by means of two Foster automatic indicating controllers, one for each zone, while a two-point recording instrument gives a positive check on thermal conditions along the length of the heating chamber. This recorder is fitted with excess temperature safety contacts to protect the equipment and the charge against accidental overheating.



This electric furnace for heating aluminium billets is rated at 165kW with a maximum output of 1680 lb per hour at 450 deg. Cent. The charging end, with the electrically operated hoist and pusher gear, is on the left

Surface Roughness Scales

A set of surface roughness scales now being made by Rubert and Co., Ltd., Chapel Street, Stockport Road, Manchester, 19, is designed to provide a simple and ready form of comparison with the quality of finish on machined components. When using these scales the surface of a component is lightly " felt " with the tip of the finger nail and a comparison is made with that on the appropriate scales. The maker points out that, although it is not possible to determine the precise value in micro-inches of a surface finish with the scales, it is possible to determine that a surface finish is within certain limits—for instance, better than 32 micro-inches but not as good as 16 micro-inches. In addition to being particularly sensitive to degrees of surface roughness, the finger nail has an added advantage in that it is relatively soft and will not damage or scratch a highly-finished surface.

For general workshop use the firm makes a set of ten stainless steel specimens mounted in a pocket folder. The specimens in this set are according to B.S.S. 1134 : 1950, and are finished to from 1 to 500 micro-inches C.L.A. by lapping, grinding, milling, shaping, or turning, as indicated on the scales. A full set of thirty stainless steel specimens, each 1in by ⅜in, and ten round carbon steel specimens is supplied in a wooden case. These scales are produced by different methods and cover surface finishes from 1 to 1000 micro-inches C.L.A.

V.H.F. Mobile Broadcast Link

A very-high-frequency mobile broadcast link which was used by the B.B.C. for the Boat Race sound broadcast last year is now available commercially. It is a frequency-modulation transmitter/receiver equipment (CME550 Mark II) made by Mullard Ltd. for use as a programme channel for outside broadcasts or similar functions. The equipment consists of a crystal controlled transmitter and receiver operating in the frequency ranges 65 to 80 Mc/s and 80 to 100 Mc/s. The receiver is used for cueing signals and instructions. By using two aerials, duplex working is possible. The transmitter consists of a phase-modulated crystal oscillator, the output of which is multiplied thirty-two times before being fed to a push-pull tetrode power amplifier giving 20W output into a coaxial aerial feeder. The carrier stability is better than one part in a million per degree Centigrade.

The receiver is a double superheterodyne with a variable first i.f. in the range 7·85 to 11·35 Mc/s and a second i.f. of 1·5 Mc/s. The first frequency changer is fed from a crystal oscillator frequency multiplier chain which selects the ninth harmonic of the crystal. The fundamental frequency of the crystal is injected into the second mixer to produce an i.f. of 1·5 Mc/s. Both frequency range and stability are identical with those of the transmitter. All spurious responses are 65 db below the level of the signal, and the sensitivity is 10 microvolt for a signal to noise ratio of 40 db. Two limiters are used, and the r.f. and i.f. amplification is such that they saturate on random noise in the no-signal condition. The output for all signals is constant at 4 db above 1mW in 600 ohms. Power for the transmitter and receiver comes from a slow-running rotary converter operated from a 6V or a 12V d.c. supply. Alternatively an a.c. power supply unit can be supplied.

Highway Improvements for New York City

BY OUR AMERICAN EDITOR

As the result of a joint review of New York's traffic problem by the Port of New York Authority and the Triborough Bridge Authority, an ambitious arterial highway and toll bridge programme for the New York area has now been published. From a structural engineering point of view its highlights are the much-discussed Narrows Bridge linking Brooklyn and Staten Island, the Throgs Neck Bridge over the East River a mile east of the Bronx-Whitestone Bridge, and an additional six-lane lower deck for the George Washington Bridge. In spite of the magnitude of the works now proposed there is already considerable criticism claiming that the scheme, while involving the expenditure of 600 million dollars, will contribute only modestly to the relief of New York City's acute traffic congestion. It has been estimated that the improvements contemplated will remove 3,000,000 vehicles a year from Manhattan. These vehicles constitute through traffic that has neither need nor desire to be caught in Manhattan's traffic jams, but now can find no way to by-pass the choked streets of this borough. The principal relief will be felt around the approaches to the Lincoln and Holland tunnels and the George Washington Bridge. But the basic intra-city traffic problem of Manhattan will not be materially improved by the present programme. For example, it recommended no action on the much needed cross-town expressways —one across Thirtieth Street to link the Lincoln and Queens Midtown tunnels, and the other to end the long, slow trek across Canal and Broome Streets between the Holland tunnel and the Manhattan and Williamsburg bridges. Unfortunately, these cross-town expressway schemes are particularly expensive and would not pay for themselves, since they would have to be toll-free. While the need for the cross-Manhattan elevated express route remains unchallenged, no angel to finance them is in sight. The two main authorities are limited to "self-supporting" ventures; New York City has no money for major highway construction, and the only vague hope is that someone will convince the Federal or State Governments that the crossings are in some way a part of the arterial plan to which they legally could contribute funds. Thus Manhattan's traffic jams remain the problem of Mayor Wagner and Traffic Commissioner Wiley. The Mayor, whose own municipal budget at present is 100 million dollars short, hopes that by some miracles of engineering Mr. Wiley can keep congestion to a minimum and with 4,500,000 dollars of revenue a year from parking meters develop a pay-as-you-go off-the-street parking scheme that will free the streets of enough vehicles to move through traffic with a minimum of delay. Many engineers are disturbed that the report accompanying the joint study of the Authorities failed to answer questions which they consider vital. What was not said—and should have been, in their opinion—was where the planners were going to put all the new traffic which the new bridges and connecting highways would lead on to Manhattan's narrow, crowded streets. The master plan of arterial routes will be of very little help to Manhattan, considering that 500,000 cars, lorries and buses crisscross the area from Fifty-ninth Street to the Battery every day. The 10,000 vehicles that the new arterial highways will divert each business day will hardly make a dent in the traffic jam.

Mr. Wiley has agreed with the general manager of the Triborough Bridge Authority that there was a real immediate need for the lower Manhattan Expressway, but he went one step further and advocated a method of paying for it. The Canal Street section is one area into which traffic is funnelled to and from the Holland Tunnel. In the Commissioner's opinion, the street system serves the tunnel rather than the other way round, so, he argues, the toll facility should pay to improve the cross-town route. Similar thinking was advanced a few years ago by Robert Moses, the Chairman of the Triborough Bridge Authority, when he proposed that a major part of a Thirtieth Street Elevated Expressway should be paid for by the Port of New York Authority because its Lincoln Tube would be a principal benefactor of the new artery. He likewise agreed that part of the financing on the East Side would be a responsibility of his agency, which operates the Queens Midtown Tunnel. However, the Port of New York Authority rejected this idea and it was dropped. And no one ever did get as far as figuring out who would pay for the middle section, from Third to Eighth Avenues. The master arterial highway plan for this region is similar to others being developed by many urban American centres and there has been much criticism of such programmes generally on the grounds that they bring traffic to a city's doorstep and then abandon responsibility for it. Only Los Angeles, California, and Houston, Texas, are constructing highway systems that conduct motorists comfortably to the hearts of these cities. The sponsors of the present programme for solving the arterial highway needs of New York region for the next two decades predict that it will meet the pressing demand for routes to by-pass the city and will offer motorists a freedom of choice in getting around the city. The new toll projects will be financed by the two Authorities, but the connecting highways will be a Federal-State responsibility and it is believed that the roads will qualify for Government grants.

The most exciting of the proposed toll bridges is the Narrows Bridge, which will provide the first direct connection between Brooklyn and Staten Island. It will be the longest suspension bridge in the world with a centre span 200ft longer than the present world champion, the 4200ft Golden Gate Bridge at San Francisco. The construction of the twelve-lane two-deck structure linking Fort Hamilton on the Brooklyn shore and Fort Wadsworth on Staten Island will involve an expenditure of 220 million dollars. Only the six-lane lower level is to be opened at first. It has been estimated that 14,500,000 vehicles a year will use the crossing, which will cut 10 miles and forty-five minutes from the trip between Brooklyn and the Jersey Turnpike "interchange" at New Brunswick, New Jersey. When traffic warrants, the upper deck and its connections will be completed. It is forecast that by 1977 the harbour crossing will handle 48,000,000 motor vehicles a year. Adjunct roads in Brooklyn will cost 39,000,000 dollars, including a new north-south artery paralleling the Belt Parkway from Fort Hamilton to the approach to the Brooklyn-Battery Tunnel. In Staten Island 30,000,000 dollars will be required to provide high-speed express connections from the Fort Wadsworth end of the structure to the three bridges now linking the least populated borough of New York City with New Jersey. Incidentally, the bridge is considered one of the salient factors in the growth forecast for Staten Island, which is expected to add 500,000 in the next two decades to its present 205,000 population. While there is little doubt that the borough will expand industrially and there will be a boom in small homes and garden flats, local planning authorities are hopeful that some way can be found to keep the "semi-rural" character of the borough. Sceptics are afraid that it will become merely a corridor for traffic wanting to by-pass Manhattan, but there is hope that the bridge will be more of a boon than a bane. The Throgs Neck Bridge over the East River will affect more property owners than the Narrows Bridge, but less opposition is expected. The structure will relieve traffic on the Bronx-Whitestone Bridge, which was built eighteen years ago at a cost of 18,000,000 dollars. This new bridge between the boroughs of Queens and Bronx and the connecting highways on its flanks are urgently required because the Bronx-Whitestone Bridge and its feeder routes are nearly at capacity. The second deck of the George Washington Bridge will be a minor engineering task because the structure originally was designed to handle a lower level. The bridge reconstruction proper will cost only 20,000,000 dollars, but approach roads costing more than 60,000,000 dollars must be built on both the New Jersey and the Manhattan sides. Last year 33,000,000 cars crossed the bridge, and although the new deck will increase capacity by 75 per cent, it is estimated that the double decks will be sufficient only to meet traffic needs till 1965. By then the bridge is expected to be handling its maximum capacity of 56,000,000 vehicles a year.

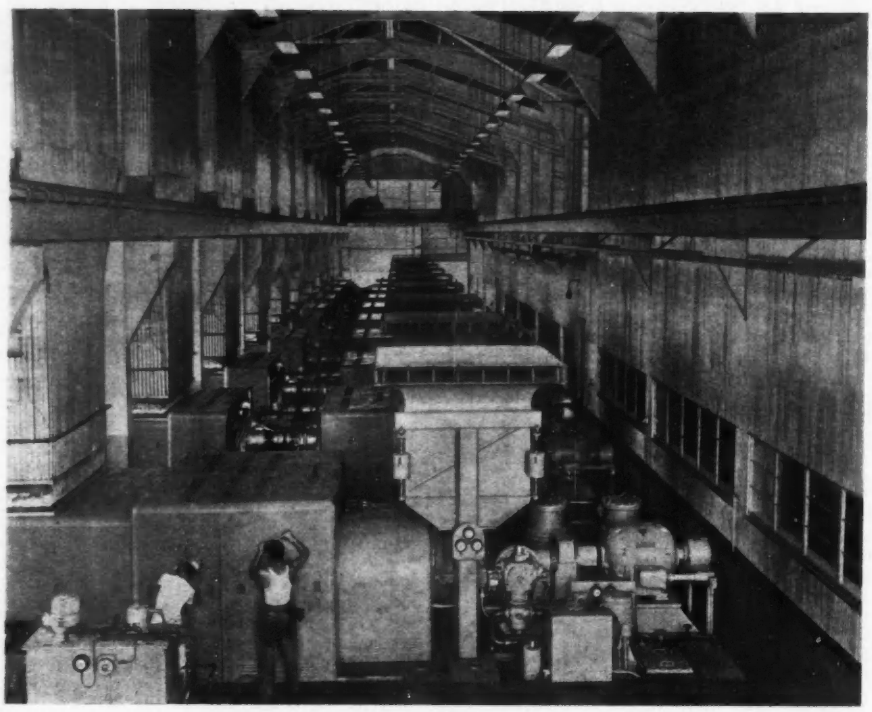
To-day, New York City's traffic problem is the problem of almost all large cities the world over, but multiplied many times: how to move freely the steadily increasing stream of cars, lorries and buses over a fixed area, virtually unchanged since the street pattern was laid out in the horse-and-cart days. The problem is complicated seriously due to years of administrative neglect and a traffic enforcement programme that has lagged twenty years behind the rest of the country. What can be done? The planning of traffic flow, lights and other controls alone will not solve the problem, although Traffic Commissioner Wiley believes it can go a long way toward increasing street capacity by moving cars through Manhattan more quickly. The City Construction Co-ordinator says that big garages spotted around the "mid-town" area can ease the parking woes. Civic leaders hold that enforcement is the crux of the problem. There are advocates, too, of night loading and unloading to keep lorries off the streets when passenger car volume is at its height, and there are champions of keeping all private cars out of "mid-town" during business hours. Commissioner Wiley is a moderate advocate of the "keep-'em-out" theory, but he would limit the ban to cars that do not contribute to business or professional activity. He has developed a long-range programme of peripheral parking lots and garages that Mayor Wagner supports and which is to be financed by parking meter revenues. There has been criticism that too many parking meters are in areas where all kerbs should be clear for moving traffic, and some meters have been removed recently. As another deterrent to cars idling at kerbs, Mr. Wiley has introduced a "no-standing" rule on major cross-town arteries that bars all vehicles from more than a moment's pause during peak periods. An extension of that rule to a wide area of the city might help to move more traffic more quickly. The one-way cross street, which has been employed in New York City since 1924, is at present being broadened to take in the long north-south avenue routes. If the longitudinal programme ever is completed, Mr. Wiley has developed a co-ordinated light signal plan that, he contends, would speed traffic flow by 25 per cent. It has been proposed to bar all left turns off main streets and avenues to end the acute snarls at intersections. Left turns now are prohibited at only a few main intersections, and Mr. Wiley is trying to determine whether extending that rule would do more good than harm. To sum up, with a present 3,500,000 and an estimated 6,000,000 cars and lorries registered in the New York-New Jersey metropolitan area in 1975, it will require every possible co-operation between the many authorities, local governments and commercial interests involved to avoid increasing chaos in the streets of Manhattan and to facilitate an orderly, well-planned system of roads to be constructed in this most densely populated region of the United States. The three major suspension bridge schemes now contemplated constitute an initial step in the right direction. But they can only provide the expected relief if ancillary highway schemes are approved to take care of the increased vehicular traffic which will result from the construction of these bridges.

EXPANSION OF BRITISH RAYON WORKS IN ALABAMA.—The production capacity of the Courtaulds viscose rayon works at LeMoyne, Alabama, will be tripled under an expansion programme approved recently by the directors of the company. The expansion programme is to be completed by next September, when the rayon works is to have a production capacity of 150,000,000 lb of staples per annum. The original Courtaulds works at LeMoyne represented an investment of more than 10,000,000 dollars. There are now about 500 workers on the payroll, and it is expected that at least 400 more will be required for the additional facilities.

Gas Conservation Plant in Venezuela

AN unusual gas conservation plant was put into operation by the Creole Petroleum Corporation of New York, at Lake Maracaibo, Venezuela, in January. The plant was designed to facilitate an immediate 50 per cent increase in oil production and a 33 per cent increase in the ultimate recovery of oil from the field where the plant is situated. An increased production efficiency results from the re-use of the gas which is a normal by-product of oil-producing operations. The gas is piped to the conservation plant for compression to a pressure of 1935 lb per square inch and is injected back into the earth at a rate of 137 million cubic feet per day. The pressure of the gas forces oil in the producing formation to the bottom end of the wells, thus increasing production and recovering oil that would not otherwise be obtainable. The new plant has been erected 14ft above the waters of Lake Maracaibo on a platform which rests on 350 concrete piles driven into the lake bed. The output of the Creole Petroleum Corporation, which is the largest oil operator in Venezuela, and other oil companies from the Maracaibo Basin now totals approximately 10 per cent of the world's crude oil production.

The plant comprises ten "Ingersoll-Rand" centrifugal compressors, capable of a 2000 lb per square inch discharge pressure. Each of the compressors is driven by a 6000 h.p. General Electric gas turbine, and it is believed that this installation constitutes the largest concentration of such turbines in the world. The gas turbines use as fuel a part of the gas which is compressed each day. Work on the plant started in February, 1953, when the first pile was driven. Construction was completed in August, 1954, and trial operations were begun in the following month. In operation, after the gas has been separated from newly produced oil, it is piped to the plant where the ten centrifugal compressors bring it up to a pressure of 1935 lb per square inch; the gas is then delivered to five injection wells through which it is returned to the producing formation. This formation consists of a tilted bed of sandstone, approximately 9800 acres in area. The oil is produced from the lower and middle parts of the formation, and the gas is injected into the upper part. The pressure of the gas forces the oil into the wells at the "bottom" end of the slab, thus increasing the production and, furthermore, sweeping before it for eventual recovery much oil that would not be obtainable otherwise. Eight "flow stations," in which the gas and oil are separated, are connected to the gas gathering system. After separation from the oil, the gas is delivered through pipelines, which range from 24in to 30in in size, to the new plant. The company had to lay about 12 miles of this pipe on the floor of the lake to carry the gas from the flow stations to the new plant. The pipe had to be specially treated and, because of its large diameter, encased in concrete to hold it on the bottom of the lake. By the time it was thus prepared, each linear foot of the 30in pipe weighed 562 lb. After the gas has been compressed it is carried by 6in and 8in lines to the five injection wells. Approximately 8 miles of such pipe were laid on the lake bed.



Installation of ten 6000 h.p. gas turbines at Lake Maracaibo, Venezuela

Symposium on Temperature

AN international symposium on "Temperature, Its Concept and Measurement," was held at the National Bureau of Standards, Washington, D.C., recently to review the present status of problems in the measurement of temperatures from milli-degrees to mega-degrees. Included for discussion in the symposium were such subjects as extremely hot gases, low-temperature scales near absolute zero, highly precise methods for measuring temperature, upper atmosphere temperatures, and the temperatures of shock waves caused by supersonic aircraft. Temperature is probably one of the most important of the physical quantities. Three international symposia have now been held to permit exchange of information between the various groups that work with extreme temperatures and precision temperature measurement; the first was in Chicago in 1919, the second in New York City in 1939. The third meeting reviewed and summarised the developments that have taken place since 1939. It opened with introductory remarks by Dr. A. V. Astin, the director of the N.B.S., who reported on the action taken in October, 1954, by the tenth general conference on weights and measures to redefine the absolute temperature scale. The general conference adopted the proposal made originally by Kelvin in 1854 and reintroduced by Giauque in 1939: to define the absolute scale of temperature on the basis of a single fixed point; this point is to be the triple point of water, to which there has been assigned the value 273·16 deg. K, exactly.

The opening session of the symposium was devoted to discussions of the general concepts of temperature. H. C. Wolfe, of Cooper Union, surveyed the general concept of temperature as applied to systems in equilibrium and outlined the procedure for establishing a temperature scale. He also pointed out the limitations to the general concept which arise in attempting to deal with non-equilibrium systems. Some special cases were treated in greater detail by F. E. Simon, of Oxford University, who discussed the concept of temperature near absolute zero, and by G. H. Dieke, of Johns Hopkins University, who outlined the procedures and difficulties involved in measuring high temperatures in gases. C. H. Payne-Gaposchkin, of Harvard University, presented a survey of the latest measurements of stellar temperatures. In a later session on transient phenomena, a group of papers were presented on the theoretical aspects of the temperature concept under non-equilibrium conditions and on the approach to equilibrium. The experimental aspects of temperature measurement were emphasised in three of the sessions. In a session entitled "Standards and Scales," there were discussions of the current status of the International Temperature Scale and of thermodynamic temperature measurements. J. A. Beattie, of the Massachusetts Institute of Technology, reviewed the nature of the problems involved in precision gas thermometry. H. Moser, of the Physikalisch-Technische Bundesanstalt, Brauschweig, described recent measurements made in his laboratory with a new gas thermometer on the thermodynamic temperature of the gold point. No determinations of the gold point temperature have been reported since the work of Day and Sosman in 1911. Moser reported that his preliminary determinations give values in essential agreement with the accepted value of 1063 deg. Cent. The maintenance of the International Temperature Scale and the methods of precision thermometry at some of the national standardising laboratories were described by J. A. Hall, of the National Physical Laboratory, Teddington, and H. F. Stimson, of the National Bureau of Standards. H. Preston-Thomas, of the Canadian National Research Council, Ottawa, reported on measurements of the stability of the freezing point of zinc, which has been suggested to replace the sulphur boiling point as a fixed point of the International Temperature Scale. At temperatures below that of the oxygen boiling point of about 90 deg. K, there is no internationally accepted "practical" scale. It is believed that in this range there is needed a scale that is realisable by thermometers more convenient than the gas thermometer but which is based on primary calibrations with the gas thermometer. The status of the scales now in use was discussed.

In a session devoted to experimental measurements, at the extremes of low and high temperature, D. de Klerk, of the Kamerlingh Onnes Laboratory, Leiden, described methods applicable to the range 0·001 deg. to 1 deg. K, and by H. van Kijk, also of Leiden, on magnetic methods for temperatures above 1 deg. K. In the high-temperature range, H. P. Broida, of the N.B.S., presented a survey of methods for temperature measurement in flames and hot gases, with particular emphasis on methods involving the measurement of radiant energy. W. Lochte-Holtgreven, of Kiel University, described experiments performed in his laboratory on high-current electric arcs in which temperatures as high as 50,000 deg. K were determined from measurements on the degree of ionisation in the arc.

Industrial temperature measurement, and the possibilities of using super-conductors and semi-conductors as thermometers were discussed. A new thermometer based on the temperature dependence of sound velocity in a gas was described by D. R. Pardue and A. L. Hedrich, of the Diamond Ordnance Fuse Laboratories. The final session of the symposium was devoted to the discussion of a number of special topics, including measurements of temperature in shock waves, in atomic explosions, and in the upper atmosphere. The publication of the symposium proceedings is being arranged by the American Institute of Physics.

Industrial and Labour Notes

Economic Outlook

Last Friday—the day after an increase in the Bank Rate to 4½ per cent had been announced—the Chancellor of the Exchequer, Mr. R. A. Butler, addressed the National Production Advisory Council. During his speech, he pointed out that the trade gap had recently widened and that the gold and dollar reserves were not rising. The terms of trade, the Chancellor said, had recently moved against us, and early last year the fall in import prices ceased as a consequence of buoyant world demand. By this January, import prices were 6 per cent higher than a year earlier, and a 6 per cent rise added almost £200 million a year to the value of this country's imports. Export prices meanwhile had been virtually steady since the middle of 1953, as a result of keen competition in overseas markets.

At the same time, the Chancellor explained, the volume of imports was rising without as yet any evidence of a marked forward movement in exports. In the four months, October to January, the value of our imports was £92,000,000 higher than in the comparable months a year earlier. Fuels, mainly coal, had accounted for 9 per cent of the increase, chemicals for 8 per cent, and non-ferrous metals for 16 per cent. Coal was an important item in the increase in the import bill, and, in addition, the need to reduce exports had lessened its earning power abroad.

An expanding economy such as ours, the Chancellor continued, was bound to consume more imports. But a growing import bill, whether it arose from a deterioration in the terms of trade, or from more imports, or as at present from both those things, could not be afforded unless there could be a corresponding increase in export earnings. Stiff competition was now the rule in world markets, the Chancellor added, and the task before this country in increasing its actual share of world trade was formidable. He went on to say that to get the best out of the highly competitive world, this country required "a tough, muscular home economy able to cope with all comers and to turn changing circumstances to its own advantage." That, the Chancellor suggested, was not precisely the state of affairs which had been emerging in recent weeks. The home economy had been so active as to be drawing in more imports than it was paying for, and had not been leaving quite enough to spare for the extra export effort that was required.

Last year, the Chancellor recalled, industrial production had risen by 6 per cent, but the rate of rise had tapered off in the final quarter. He thought that at least part of that slowing down might be attributed to our having taken up practically all the slack in the economy. Civil employment rose last year by 1¼ per cent, which included an increase of 250,000 in the number employed in manufacturing industry. Without a doubt, the Chancellor commented, labour supplies were tight ; in January, 1954, there were 17½ per cent more vacancies unfilled than a year earlier, and this January the difference had grown to 29 per cent. A substantial part of all this activity, the Chancellor observed, had been and was being devoted to productive investment, to the marked long-term benefit both of the home economy and the balance of payments. Long-term developments had been approved last summer for the electricity and gas industries, and these had now been followed by development plans for civil atomic energy, roads and railways. These long-term plans were not yet reflected in demand for capital goods, the Chancellor said, but they must be borne in mind in assessing the future. There were also signs of expansion now going on in private industry, not only new factory buildings in large numbers, but also indications of greater investment in plant and machinery. It was essential, the Chancellor concluded, that this many-sided development programme should continue without overstrain to the economy and without interference from excessive demands for goods for immediate consumption.

T.U.C.'s Budget Representations

The general council of the Trades Union Congress has made some representations to the Chancellor of the Exchequer about the 1955 Budget. In submitting them, the T.U.C. has suggested that last year Britain's economic progress owed a great deal to favourable external circumstances. World trade and production expanded, the American recession was halted, and, the T.U.C. says, the expected deterioration in the terms of trade did not materialise until towards the end of the year.

The T.U.C. goes on to say, however, that against this favourable background, the performance of our exports last year can hardly be considered satisfactory. Although the volume of exports was 5 per cent greater than in 1953, there was no expansion during the year and the level attained in the last quarter of 1953 was not reached. Furthermore, the figures for the first nine months of last year, the T.U.C. claims, show that United Kingdom exports rose much less than those of Japan, Germany and other European countries, and the United Kingdom's share in world exports of manufactures fell slightly. Nor, according to the T.U.C., were developments at home all propitious. Production rose, but the rate of increase slowed down over the year, and, despite the reduction in profits taxation and the introduction of the initial and investment allowances in the last two budgets, the major increase in industrial fixed investment, which is so essential, has not yet taken place. The over-riding objectives, in the T.U.C.'s opinion, must continue to be the need to expand exports, increase production and investment, and to stabilise costs and prices. Trade unionists, it is declared, "firmly support these objectives, but they must be satisfied that the product of their exertions is not used to line the pockets of shareholders."

The T.U.C. then goes on to its proposals. Among them there is the suggestion that the tax on distributed profits should be increased, and that a special duty, of the kind in force from 1947 to 1949, should be reimposed on bonus issues. There is also a comment about depreciation allowances. Here, the T.U.C.'s view is that, in introducing investment allowances, the Government has given "what will eventually amount to a substantial subsidy to the whole of industry." It would be far better, the T.U.C. urges, to make available larger initial allowances to firms in accordance with priorities broadly representing the national interest. Other suggestions are that the duty on fuel used by commercial road vehicles should be reduced, and that the proposals about income tax reliefs, set out in the second report of the Royal Commission on the Taxation of Profits and Income, should be accepted.

Opencast Coal

The National Coal Board has announced that the largest single contract for working opencast coal ever to be placed in Great Britain has been awarded to Richard Costain, Ltd. It is for working 5,000,000 tons of coal on the Acorn Bank Farm site in Northumberland, and has been placed by the Coal Board in pursuance of its policy of maintaining opencast output at a high level for several years to come. The site lies on the banks of the River Blyth and coal will be produced at the rate of about 750,000 tons a year for six or seven years. It covers 440 acres, of which about 300 acres will actually be mined. Three seams of coal, known locally as the high main, top grey and bottom grey, and 39in, 31in and 84in in thickness respectively, cover the whole site, and the depth of excavation will vary from 40ft to 225ft. The overburden, boulder clay, sandstone and shale, will be handled by two electric "1150-B" Bucyrus walking dragline excavators. In addition, three electrically operated rock shovels will be used as well as American air drills. The coal will be transported to the Bebside disposal point near Blyth, where it will be crushed, screened and sized, mainly for the seaborne and export markets. So that the site can be returned to agricultural use as quickly as possible, work is to start from the deepest end first. A pair of road tunnels will be laid to the bottom of the "cut" to allow the coal to be transported to the surface while the site is being worked. These tunnels will be covered over as the work advances across the site.

Index of Industrial Production

The Treasury has stated that the index number of industrial production (1948=100), which is prepared by its central statistical office, has been estimated at 128 for all industries in December last, compared with a revised figure of 139 for November. Figures for the corresponding months a year earlier were 121 in December and 133 in November. An analysis of the various industrial groups in December shows that the index for the manufacturing industries was 132, compared with 123 a year earlier ; for mining and quarrying it was 107, compared with 108, and for gas, electricity and water supply, the index number was 161, compared with 148 in December, 1953. The Treasury says that on the information it has so far received the index for all industries in the month of January is expected to be 132 or 133. In January last year it was 127.

Wage Rates and Earnings

The Ministry of Labour reports that changes in wage rates which came into operation in January in the United Kingdom resulted in an aggregate increase of about £739,000 in the weekly full-time wages of 2,685,000 workpeople. Among those who received wage increases were the employees of British Railways, other than locomotive running staff, workers in the electricity supply industry, and in the iron and steel industry. The increases in the iron and steel industry were payable under sliding scale arrangements based on the index of retail prices. Manual workers employed in electricity supply undertakings received an increase in scheduled rates of 3d. an hour, and there were further increases of a halfpenny or penny an hour for certain specified grades. The increases to the conciliation staff of British Railways ranged generally from 6s. to 9s. a week, according to grade and service. The changes in January brought the index of rates of wages (June 30, 1947=100) to 146 for all workers, which indicated a rise of two points during the month.

The Ministry of Labour has also published some preliminary details about the results of its half-yearly inquiry into the average weekly earnings of manual workers. The inquiry concerned the last pay week in October, 1954, and relates to about 7,000,000 manual workers in the manufacturing industries and a number of non-manufacturing industries in the United Kingdom. The average weekly earnings of all the workers (men, youths, women and girls) in the industries covered, inclusive of bonuses and overtime and before deduction of income tax or insurance contributions, amounted to £8 11s. 9d. This represented an increase of 3 per cent since April, 1954, and an increase of 223 per cent since October, 1938. The average weekly hours worked in the last pay week of October, 1954, were 46·7, compared with 46·5 in October, 1938. For men of twenty-one and over, the Ministry says, the average weekly earnings in October last year were £10 4s. 5d., compared with £9 17s. 8d. in April, 1954, and £3 9s. in October, 1938. Average weekly hours worked last October were 48·5, compared with 48·3 in April, 1954, and 47·7 in October, 1938. In the manufacturing industries only, the average weekly earnings of all workers were £8 10s. 10d. in October last, compared with £8 5s. 5d. in April, 1954. The average weekly earnings of men in those industries were £10 12s. 2d., compared with £10 5s. 2d. in April last year.

Personal and Business

Appointments

MR. C. WILSON has been appointed deputy general manager of the Machine Tool Trades Association.

MR. D. W. BOTTLE, A.C.G.I., has been appointed chief aerodynamicist of Short Brothers and Harland, Ltd., Belfast.

SQUADRON LEADER L. M. WHITTINGTON has joined Folland Aircraft, Ltd., Southampton, as assistant to the chief test pilot.

MR. S. ROBERTS has been appointed managing director of Hoover, Ltd., Perivale, Middlesex. He succeeds Mr. J. A. Wykes, who has retired from the board on account of ill health.

MR. DOUGLAS RAMSDEN has been appointed secretary and a director of Villiers Australia Pty. Ltd., Ballaarat, a subsidiary of the Villiers Engineering Company, Ltd., Wolverhampton.

MR. F. R. MASON has been appointed general manager of Metropolitan-Vickers Electrical Export Company, Ltd., and Mr. G. H. Jolley has succeeded him as the company's principal representative at Trafford Park.

SIR JOHN GREEN has joined the board of Thos. Firth and John Brown, Ltd., and has been appointed chairman of the company. Dr. C. Sykes has been appointed deputy chairman in addition to his office as managing director.

THE MARCONI INTERNATIONAL MARINE COMMUNICATION COMPANY, Ltd., announces the appointmnet of Mr. A. P. Goodman as depot manager at Aberdeen, in succession to Mr. V. G. Oastler, who has been transferred to the company's main London depot at East Ham as deputy manager.

SIEMENS ELECTRIC LAMPS AND SUPPLIES, Ltd., 38–39, Upper Thames Street, London, E.C.4, announces the appointment of assistant area managers as follows :—Mr. H. A. Page, Birmingham ; Mr. J. E. Walker, Belfast ; Mr. F. Smith, Sheffield ; Mr. H. Chambers, London, and Mr. T. O. Wilkins, Bristol.

THE SOCIETY OF MOTOR MANUFACTURERS AND TRADERS states that, following the appointment of Mr. Stanley Clark as chief executive, Mr. D. E. Gough has become manager of the British manufacturers' section as well as overseas secretary. Mr. W. T. Williams, formerly head of the legal department, has been appointed secretary.

CAPTAIN A. R. MANGNALL, chairman and managing director of the Hydraulic Engineering Company, Ltd., Chester, has joined the boards of the General Hydraulic Power Company, Ltd., the Hatfield Insurance Company, Ltd., Hypower, Ltd., the Liverpool Hydraulic Power Company, and the London Hydraulic Power Company.

Business Announcements

JENOLITE, Ltd., states that it is moving to new premises at 13–17, Rathbone Street, London, W.1 (telephone, Museum 5411).

MR. A. UPTON, manager of the switchgear department of Johnson and Phillips, Ltd., has left this country to visit Karachi, Calcutta and Bombay.

S. W. CARTY AND SON, 12, Lower Mount Street, Dublin, are now acting as agents in Eire for the Pulsometer Engineering Company, Ltd., Reading.

MR. J. E. SHERLOCK, chairman of Teddington Industrial Equipment, Ltd., Sunbury-on-Thames, is engaged on a five-weeks' tour of Australia and New Zealand.

SIEMENS ELECTRIC LAMPS AND SUPPLIES, Ltd., is opening a new branch office and depot, on March 31st, at West Bay Road, New Docks, Southampton. Mr. A. Shaw is to be the manager.

CLAUDE-GENERAL NEON LIGHTS, Ltd., Pitman House, Parker Street, London, W.C.2, states that an exclusive manufacturing licence for the U.S.A. has been granted to Voltarc Tubes Inc.

KINGSTON CONTROL SYSTEMS, Ltd., Empire Chambers, Richmond Road, Kingston-on-Thames, has recently been incorporated to design and supply automatic control and instrumentation systems.

THE BRITISH WEDGE WIRE COMPANY, Ltd., Warrington, has moved its London office to Elmswood House, Bounds Green Road, N.11 (telephone, Bowes Park 8442 ; telegraphic address, " Modmec, London, N.11 ").

ASSOCIATED COMMERCIAL VEHICLES, Ltd., states that a new body sales division has been formed within the group. It is known as the Park Royal Group Body Sales Division, and results from the merging of the bodywork selling organisations of Park Royal Vehicles, Ltd., Charles H. Roe, Ltd., and Crossley Motors, Ltd. (Body Works). All body sales matters within the group will in future be handled by the new division, which is established at the head office of Park Royal Vehicles, Ltd., Abbey Road, London, N.W.10.

FREDERICK C. KANE, Ltd., Park Royal, London, N.W.10, has completed arrangements for the manufacture in this country of food processing machinery designed and produced by Chisholm Ryder Company Inc., of the U.S.A.

GOODENOUGH PUMPS, Ltd., Twickenham, states that arrangements have been made for its pumps to be manufactured in Canada by Godfrey Engineering Company, Ltd., 480, Metropolitan Boulevard, Lachine, Montreal, 52.

E. AND L. B. PINKNEY (MARINE), Ltd., Zetland Road, Middlesbrough, has taken over the production and marketing of " Feltham " marine engines and reversing gears formerly produced by Bruce and Holroyd, Ltd., Feltham, Middlesex.

CRAVENS, Ltd., Sheffield, announces the retirement from its board of directors of Mr. A. E. Cook. Mr. Cook has been in the company's service for forty-four years, having been engineer, works manager, general manager and managing director.

THE EXPORT CREDITS GUARANTEE DEPARTMENT has opened a new branch at Newcastle upon Tyne to serve the Tyneside, Wearside and Tees-side area. Mr. J. A. Bookless is the manager of the branch, the temporary headquarters being at 93A, Grey Street, Newcastle upon Tyne, 1 (telephone, Newcastle 26011).

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., states that Sir Arthur Fleming, director of research and education, has retired from executive duties. He is being retained as a consultant. Mr. E. P. Grimsdick, assistant to the managing director, has retired from executive duties, and is being retained as a consultant on matters concerning India and Pakistan.

THE DAVID BROWN CORPORATION, Ltd., Huddersfield, states that arrangements have now been completed for the purchase of a controlling interest in Harrison, McGregor and Guest, Ltd., agricultural engineers, Leigh, Lancs. The board of Harrison, McGregor and Guest has consequently been reconstituted to include Mr. David Brown, Mr. J. C. R. Birney, Mr. Walter Drew and Mr. J. Whitehead.

Contracts

HEAD, WRIGHTSON AND CO., Ltd., Thornaby-on-Tees, has received from the British Transport Commission an order for 111 fifty-ton rail, ballast and sleeper wagons.

RICHARD SUTCLIFFE, Ltd., Horbury, Wakefield, announces that it has received an order, valued at nearly £500,000, for the complete mechanical plant for the Irlam development scheme of the Lancashire Steel Corporation, Ltd. The order includes fifteen 36in wide belt conveyors, five plate feeders and ancillary belt trippers, crusher and junction houses, wagon tippler, grizzly screens and cone crushers.

THE LONDON MIDLAND REGION of British Railways states that work has begun on a £400,000 scheme for rail sidings, a new bridge and ancillary works to serve the National Coal Board's carbonisation plant at Clay Cross. There is to be a group of sidings on one side of the Derby-Leeds main line, a twin track rail bridge over the main line into the plant on the opposite side and signalling and other alterations. Leonard Fairclough, Ltd., is the principal contractor and The Butterley Company, Ltd., is supplying the steelwork for the new bridge.

THE JOHN INGLIS COMPANY OF TORONTO, Ontario, the Canadian associate of The English Electric Company, Ltd., has received an order from the Hydro-Electric Power Commission of Ontario for sixteen 75,000 h.p. fixed-propeller water turbines, valued at 7,500,000 dollars. It comprises the complete turbine installation on the Canadian side of the St. Lawrence water power project. The equipment will be manufactured at the company's works in Toronto to the designs of The English Electric Company, Ltd., England.

THE ENGLISH ELECTRIC COMPANY, Ltd., has received an order from the British Electricity Authority for a 200MW turbo-alternator. An order has also been placed with International Combustion, Ltd., for the associated pulverised fuel boiler plant. The boiler will be designed to generate 1,400,000 pounds of steam per hour at 2450 lb per square inch and 1060 deg. Fah., with reheat to 1005 deg. Fah. The turbo-alternator and boiler, are the first of five similar units which will be installed in a new power station to be built on the River Trent. Subject to the consent of the Minister of Fuel and Power for the establishment of this station, it will be built on a site provisionally selected at High Marnham.

Miscellanea

KWINANA REFINERY.—The Kwinana refinery, near Fremantle, Western Australia, which has a capacity of 3,000,000 tons a year, came on stream on February 1st with the commissioning of the first distillation unit.

" THE OILSEAL JOURNAL."—We have received from the Pioneer Oilsealing and Moulding Company, Ltd., of Colne, Lancs, the first issue of its new house magazine, *Oilseal Journal*. This journal is to be published quarterly and is intended to assist industrial designers and users of oilsealing devices in discussing and describing the firm's products and their applications.

SYMPOSIUM ON EXTRACTION METALLURGY.—The Institution of Mining and Metallurgy announces that it has been necessary to postpone the symposium on the extraction metallurgy of some of the less common metals, which was to have been held in September next. The symposium will now be held in London on Thursday and Friday, March 22 and 23, 1956. Further particulars will be published later.

LAUNCH OF PATROL VESSEL.—Les Chantiers et Ateliers Augustin Normand launched the Patrol Boat " P5 " on February 9th. The boat has the following dimensions :—Length overall, 173ft 8½in ; length between perpendiculars, 170ft ; breadth moulded 22ft ; draught, 6ft 5in ; displacement, 380 tons, and is propelled at 18·7 knots service speed by twin screws driven by four fourteen-cylinder S.E.M.T.-Pielstick diesel engines of 3500 total horsepower.

IRON AND STEEL ENGINEERS' GROUP.—The Iron and Steel Institute has announced that the twenty-eighth meeting of its iron and steel engineers' group is to be held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2, on Wednesday, March 23rd. At the morning session, beginning at 10.30 a.m., a paper entitled " Some Comments on Waste Heat Recovery Practice " will be presented by Captain (E.) W. Gregson, of Spencer-Bonecourt, Ltd. At the afternoon session, at 2 p.m., Mr. W. Ernest, of the United Steel Companies, Ltd., will present a paper entitled " Waste Heat Recovery, with Particular Reference to the Generation of Electric Power."

LILLE INTERNATIONAL FAIR.—This year marks the thirtieth anniversary of the creation of the Lille International and Commercial Fair in France. The reconstruction of the buildings destroyed during the second world war has now been completed and the total superficial area of the Fair covers a surface of 200,000 square metres, of which 80,000 square metres are covered by halls of modern construction and adapted for the different sections which they house. The 10,000 square metres covered by the Grand Palace are not sufficient to accommodate the whole of the automobile and cycle sections. There is also to be a mechanical section and exhibits of plastic materials and office equipment. The other twenty-five sections of the Fair, which are contained in seven other large buildings, are now practically completed. The Fair will be held from April 23rd till May 8th.

MR. CEDRIC P. LOCKTON.—We regret to have to record the death, on February 20th, of Mr. C. P. Lockton, M.Sc. Tech., M.I.E.E., chief engineer of Chloride Batteries, Ltd. Cedric Phillips Lockton was born in 1903 and educated at Berkhamsted School, Herts, and at the Manchester College of Technology, where he studied electrical engineering under Professor Miles Walker, a contemporary and friend of his father. After obtaining the degree of M.Sc. Tech. in 1923 he joined the British Electrical Plant Company, Ltd., of Alloa, Scotland, to work on the design of small electric motors and dynamos. In September, 1924, he was engaged by the Chloride Electrical Storage Company, Ltd., as assistant to the chief engineer. He specialised chiefly on the technical problems of portable and semi-portable batteries, with particular reference to development work, and during the war he was largely engaged in technical liaison with the Admiralty, War Office and Air Ministry on their many battery problems. In October, 1949, he was appointed chief engineer to the company, which shortly afterwards changed its name to Chloride Batteries, Ltd., and still held this position at the time of his death.

SINGLE PHASE 50 c/s ELECTRIC LOCOMOTIVES ON FRENCH RAILWAYS.—In our article " Electrical Engineering in 1954 " (January 14th, page 61, col. 3), we described a prototype C_0-C_0 locomotive on the electrified lines of French Railways between Mezières, Charleville and Thionville. We have since been informed by Alsthom, the maker of this locomotive, that our description is incorrect. The following particulars are given by the maker. The equipment is a C_0-C_0 locomotive weighing 125 metric tons, including 7 tons ballast. It was designed and built by Alsthom with a continuous rating of 2500 h.p. (at wheel rims) at 18·2 m.p.h., to haul very heavy freight trains. It is driven by six d.c. double reduction traction motors which are supplied at approximately constant horsepower input by two generators driven by a 1500 r.p.m. single phase synchronous motor. The traction motors are provided with two main field windings : one series and one separately fed by a special exciter which is used during motoring to give an " anti-shunt " characteristic or, during regenerative braking, to provide the excitation of the motors. The locomotive, 14101, the prototype of a series of 102, was delivered on July 29th and by December 31st it had covered 56,000 miles (a daily average of 370 miles), hauling trains with an average weight of 1360 tons and a maximum of 1850 tons. Several starting tests have been made on rising gradients and the locomotive has established its ability to start a load of 2080 metric tons on a gradient of 1 : 100.

British Patent Specifications

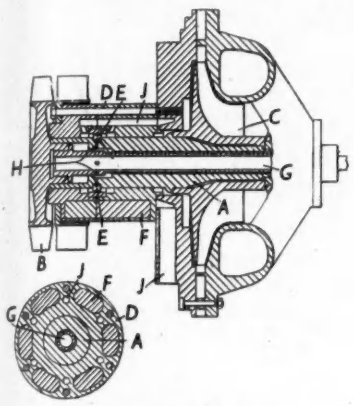
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

BEARINGS AND SUPPORTS

723,237. January 21, 1952.—Machinery Bearings, The Rover Company, Ltd., Meteor Works, Lode Lane, Solihull, Birmingham. (*Inventor: Francis Robert Bell.*)

The invention relates to machinery bearings which are exposed to, or receive heat by conduction from, a region of high temperature, such as a bearing for a shaft which at one end carries the rotor of a gas turbine. Referring to the drawing, there is shown a shaft *A* which at one end carries the rotor *B* of a gas turbine, and at the other end the rotor *C* of an air blower. The end of the shaft adjacent to the turbine rotor is supported in a stationary bearing *D*, which may include a ring of bearing rollers *E*. In the



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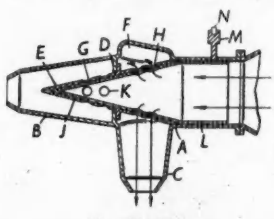
bearing is a longitudinal cavity or cavities, each of which is filled with an alloy *F* having an appropriate low fusion temperature. A convenient alloy consists of equal amounts of lead and zinc, the fusion temperature being about 200 deg. Cent. The amount of alloy incorporated with the bearing is such that on fusion its latent heat of fusion will minimise any further increase of temperature in the bearing due to heat flow along the shaft and bearing from the turbine after it has been brought to rest. The bearing is oil cooled to a temperature below the fusion point of the alloy. The oil is introduced to an axial bore *G* in the shaft at the blower end and is conducted therefrom through radial passages *H* adjacent to the turbine end of the shaft to discharge passages *J*.—*February* 2, 1955.

AERONAUTICAL ENGINEERING

723,160. July 8, 1952.—Jet Deflectors for Aircraft, Power Jets (Research and Development), Ltd., 25, Green Street, London, W.1. (*Inventor: Peter Frederick Ashwood.*)

The invention relates to a jet diverter for diverting an aircraft propulsive jet from the rearward direction to a lateral direction and, in particular, for diverting the jet downwards for providing upthrust on occasion. The simple operating mechanism allows the jet to be very rapidly diverted by only a small movement of the diverter from one operative position to the other. In the drawing a sectional view of a diverter is shown



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within a jet pipe taken in a vertical plane through the longitudinal axis of the jet pipe with the jet diverted downwards; a similar drawing shows the jet directed rearwards. The jet pipe *A* has a nozzle *B* and a downward nozzle *C*. An annular shoulder *D* is formed within the jet pipe at the upstream end of the rearwardly directed nozzle *B*. The shutter device is formed by two conical sleeves, nested one within the other. An outer and fixed sleeve *E* abuts the shoulder *D* substantially midway along its axis, the apex portion of the conical sleeve extending into the nozzle *B*. The base of the conical sleeve *E* abuts or is formed integrally with the jet pipe upstream of the nozzles. Surrounding the sleeve *E* upstream of the shoulder *D* is an enlargement of the jet pipe which forms an annular collecting chamber *F* which communicates with the downwardly directed nozzle *C*. The outer sleeve has apertures *G* in its wall through which the jet gases may pass into the nozzle *B* and other apertures *H* in its wall through which the jet gases may pass into the annular chamber *F*. An inner conical sleeve *J* fits closely within the outer sleeve *E* and has apertures *K* in its wall so located that on rotating the inner sleeve about its longitudinal axis the apertures may be brought to register with the apertures in the outer sleeve to provide a path for the jet gases to the nozzle *B*. Other apertures in the inner sleeve are so located that they may be brought to register with the apertures *H* in the outer sleeve to provide a gas path to the nozzle *C*. By making the apertures in both sleeves in the shape of longitudinal slits with the two sets of apertures spaced apart radially by a smaller angle, only that smaller angle of rotation is required to obtain deflection of the jet. The conical sleeve has a circular extension *L* and a lug M on the inner sleeve *J*, which is connected to the actuating lever *N*.—*February* 2, 1955.

FURNACES

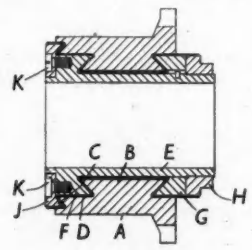
722,898. July 11, 1951.—Oil-Fired Furnaces, Reginald Bruce Cooper and Associated British Combustion, Ltd., both of Meonstoke, Hampshire.

The invention relates to oil-fired furnaces for steam boilers. It provides a means of meeting the varied demands in output in an installation comprising a number of oil burners, some of different sizes, to which combustion air under pressure is supplied. Each burner has an air register and quarl or brick throat of a size appropriate to its sprayer, whereby all the burners have the same draught-loss characteristics. In British Patent Specification No. 169,828 there is described and illustrated an arrangement for oil firing locomotive boilers consisting of several oil burners of similar size, each housed in an air box to which pressure air for combustion is fed. There is further provided a pilot burner for use in starting-up or standing-by. In a typical installation for a ship's boilers each boiler would be fired by, say, three 14in registers, one 12in and one 6in. These burners would consume approximately 800 lb, 600 lb and 200 lb of oil per hour, respectively. From the above it will be seen that if a given boiler has a sufficient number of different sized burners to serve it, then it is possible, whatever the output, to steam with a constant air pressure from the forced draught fans provided the furnace pressure remained constant. Further, the presence of one or more small burners obviates the necessity of changing atomisers for different outputs.—*February* 2, 1955.

ELECTRICAL ENGINEERING

718,709. July 23, 1951.—Commutators for Dynamos, Rotax, Ltd., Chandos Road, Willesden, London, N.W.10. (*Inventor: Sydney Lucas.*)

The invention relates to commutators for dynamo-electric machines and its purpose is to prevent deformation of the segments by centrifugal force at very high speeds. Referring to the drawing, each segment *A* has formed on its inner edge a dovetail *B* which is made relatively narrower than the conventional dovetail, and is disposed at or near the centre of the segment. Also at one or each



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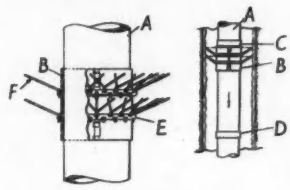
end there is formed in the segment a notch *C* having one edge parallel with the outer edge of the segment and having its other edge tapered towards the inner edge. The assembly of segments is mounted with intermediate insulating strips *D* on a cylindrical bush *E* and on the bush are provided retaining collars *F* and *G* shaped to engage the opposite ends of the dovetail. In the example shown the collar *F* is formed integrally with the bush, and the collar *G* consists of a separately formed ring which is held in position by another ring *H* screwed on the bush. Also an additional retaining collar *J* secured by screws *K* to one end of the bush is provided to engage the notch in the adjacent ends of the segments. By means of the construction described, deformation of the segments by centrifugal force at high speeds can be effectively prevented.—*November* 17, 1954.

CIVIL ENGINEERING

721,960. April 1, 1952.—Well Bore Scratcher Device, Baker Oil Tools, Inc., 6000, South Boyle Avenue, Los Angeles, California, U.S.A. (*Inventors: Reuben Carlton Baker, Thomas McClanahan Ragan and James Scott Gassaway.*)

The invention relates to a device for scratching or scraping the walls of open well bores and conduits of various kinds when re-cementing. As the drawing



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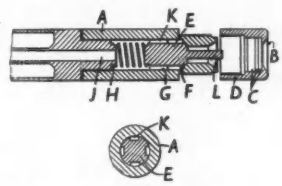
shows, the scratcher is mounted on a casing section *A* for the purpose of removing deposits of mud cake and centring the casing string in the well bore. It consists of a collar or sleeve *B*, which is slidable on the casing section, its movement being confined by the stop elements *C* and *D*. The collar has two beaded strips *E* with series of holes offset with respect to the holes in the other row. The scratcher spring fingers *F* consist of long finger elements connected by coil portions, which give the necessary flexibility to the finger elements. In the specification various types of spring fingers and coil arrangements are also shown.—*January* 19, 1955.

OIL BURNERS AND SPRAYERS

722,951. August 29, 1952.—Oil Burners for Marine Service, Associated British Combustion, Ltd., Meonstoke, Hampshire. (*Inventor: Reginald Bruce Cooper.*)

The invention relates to an oil burner for marine service with a sprayer body fitted at its discharge end with atomiser plates or atomiser cap through which the oil passes and is atomised before entering the furnace. Its object is to provide means which will ensure that in the event of the atomiser plates or cap being left off the sprayer body, no oil can possibly pass through the discharge end of the sprayer. Referring to the drawings, the sprayer comprises the body *A* fitted at its discharge end with an atomiser *B*, detachable for cleaning purposes. The means provided by the invention for preventing discharge of oil when the atomiser cap or plates are not in position



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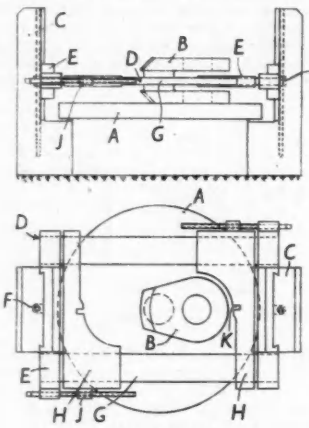
comprises a spring-loaded valve *E* fitted within the discharge end of the sprayer body *A*. When the atomiser *B* or plates *C* are not in position the valve is urged against a seating *F* formed in the inner wall *G* of the body *A*, so that no oil can pass. The spring may conveniently be interposed between a shoulder *H* at the discharge end of the spray tube *J* and the rear end of the valve *E*, which is thus pressed at its forward end against the seating. The circumferential wall of the valve is formed with grooves or recesses *K*, through which the oil can pass from the rear of the valve to the front end. The front end of the valve is fitted with a rod or web *L*, which, when the atomiser *B* or atomiser plates *C* in the cap *D* are fitted to the discharge end of the body *A*, is engaged and moved rearwards to move the valve *E* off its seating against the influence of its spring. Thus should the atomiser be omitted, or if the atomiser plates are omitted from the sprayer cap nut, the spring-loaded valve will remain closed under the influence of its spring, and if the sprayer body is inserted in the burner and the oil valve turned on, no oil will pass out of the sprayer body.—*February* 2, 1955.

MACHINE TOOLS

723,167. August 26, 1952.—Machining Individual Cranks of Large Crankshafts, Heinz Specht, Humboldstrasse 53, Dusseldorf, Germany.

The machine illustrated in the drawing comprises a work table *A* arranged to rotate about a vertical axis and to which a crank *B* may be secured with its

coaxial pin. Two uprights *C* are rigidly secured to the fixed bed-plate of the work table at diametrically opposed points and extend above the work table without any transverse connection except by a tool carrier *D*. The tool carrier comprises a pair of slides *E* mounted on the uprights and adjustable vertically by means of a screw and nut mechanism indicated at *F*, a pair of laterally disposed bars *G* connecting the



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ends of the slides, and a pair of tool holders *H* mounted on the bars *G* are adjustable along them by means of a screw and nut mechanism *J*. Tools are inserted and secured in the slots *K*. In operation a crank *B* is secured to the work table and the tool holders *H* are adjusted along the bars *G* until the tools engage the crankpin so that they will cut into it to the required depth. The tool holders *H* are then clamped to the bars *G*. The work table is rotated and the screw and nut mechanisms *F* are driven in unison to cause the tool carrier to move vertically so that the desired cutting operation is effected over the length of the crankpin.—*February* 2, 1955.

Catalogues

KOEHRING COMPANY, Milwaukee, Wisconsin, U.S.A.—Leaflet describing a 20-ton lift crane.

AUTO DIESELS, Ltd., Uxbridge.—Brochures describing self-priming pumps and generating sets.

METRO-CUTANIT, Ltd., Grappenhall, Warrington, Lancashire.—Leaflet "Elmet Contact Metals."

E.M.I. FACTORIES, Ltd., Hayes, Middlesex.—Leaflet describing the E.M.I. 12kW induction heater EH.120.

NEWTON CHAMBERS AND CO., Ltd., Thorncliffe, near Sheffield.—Brochure entitled "Success is not an Accident."

LAMBERT ENGINEERING COMPANY (GLASGOW), Ltd., Kelvin Dock, Maryhill Road, Glasgow, N.W.—Leaflet describing the "Hydrocon" Mark IV, 3-ton mobile crane.

CYRIL ADAMS AND CO., Ltd., 155, East Barnet Road, New Barnet.—Illustrated brochure describing the "Cadamco" service of special-purpose tool and machine design.

FOOD MACHINERY ASSOCIATION, 14, Suffolk Street, London, S.W.1.—"British Dairy Equipment." The Association's illustrated directory of the products of its members.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., March 9th.—N.E. SECTION: Neville Hall, Westgate Road, Newcastle upon Tyne, "The Application of Negative Feedback to Electrical Measuring Instruments," F. J. U. Ritson, 6 p.m.——W. MIDLANDS SECTION: Technical College, Wulfruna Street, Wolverhampton, "Electrical Standards in Electronics," P. M. Clifford, 7.15 p.m.

Thurs., March 10th.—SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Computing Circuits in Flight Simulators," R. A. Marvin, 7 p.m.

CHEMICAL SOCIETY

Thurs., March 10th.—EDINBURGH BRANCH: North British Station Hotel, Edinburgh, "The Changing Face of the Gas Industry," A. Marsden, 7.30 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., March 8th.—Church Institute, Hull, "Silver and Platinum in the Chemical Industry," J. M. Pirie, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., March 8th.—STOKE-ON-TRENT GROUP: Midlands Electricity Board, 31, Kingsway, Stoke-on-Trent, "Home Lighting," J. W. Stewart, 6 p.m.

Wed., March 9th.—Royal Institution, Albemarle Street, London, W.1, Trotter-Paterson Memorial Lecture, Sir Harold Spencer Jones, 6 p.m.

INCORPORATED PLANT ENGINEERS

Tues., March 8th.—EDINBURGH BRANCH: 25, Charlotte Square, Edinburgh, Annual General Meeting, 7 p.m.

Wed., March 9th.—E. MIDLANDS BRANCH: Adult Education Centre, Shakespeare Street, Nottingham, Annual General Meeting, 7 p.m.——GLASGOW BRANCH: Scottish Building Centre, 425/427, Sauchiehall Street, Glasgow, Annual General Meeting, "Civil Engineering Problems and Their Solutions," D. Pentland, 7 p.m.

Thurs., March 10th.—N.E. BRANCH: Roadway House, Oxford Street, Newcastle upon Tyne, Annual General Meeting, 7 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

To-day, March 4th.—TEES-SIDE BRANCH: Teesdale Hall, Head, Wrightson and Co., Ltd., Thornaby-on-Tees, "The Exothermic Feeding of Castings," D. V. Atterton, 7.30 p.m.

Mon., March 7th.—SHEFFIELD BRANCH: College of Technology, Pond Street, Sheffield, "The Place of Shell Moulding in the Foundry," B. H. C. Waters, 7.15 p.m.

Wed., March 9th.—BURNLEY SECTION: Municipal College, Ormerod Road, Burnley, Annual General Meeting, "Shell Moulding and the Economic Use of Shell Moulding Materials," R. K. Jackson, 7.30 p.m.

Thurs., March 10th.—LINCOLNSHIRE BRANCH: Technical College, Lincoln, "Castings for the Smithy and Forging Industry," W. S. Spenceley, 7.15 p.m.——BEDS/HERTS SECTION: W. H. Allen, Sons and Co., Ltd., Bedford, "Production of Moulds and Cores by the Carbon Dioxide Process," D. V. Atterton, 7.30 p.m.——SOUTHAMPTON SECTION: Technical College, St. Mary's Street, Southampton, "Assisted Feeding of Castings," A. Logan; Film, "Aluminium Alloy Match Plates," 7.30 p.m.

INSTITUTE OF FUEL

To-day, March 4th.—S. WALES SECTION: Y.M.C.A., Kingsway, Swansea, "Atomic Energy," P. McNair, 6 p.m.

Thurs., March 10th.—Institution of Civil Engineers, Great George Street, London, S.W.1, "Fuel Developments in Germany," W. Gumz, 5.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., March 8th.—85, Minories, London, E.C.3, "Application of Modern Instrumentation and Distance Control of Machinery," R. H. Paddon Row, 5.30 p.m.

INSTITUTE OF METALS

Mon., March 7th.—SHEFFIELD LOCAL SECTION: College of Technology, Pond Street, Sheffield, "The Place of Shell Moulding in the Foundry," B. H. C. Waters, 7.15 p.m.

Tues., March 8th.—S. WALES LOCAL SECTION: University College, Singleton Park, Swansea, "Industrial Methods of Electroplating," G. E. Gardam, 6.45 p.m.

INSTITUTE OF PETROLEUM

Wed., March 9th.—Manson House, 26, Portland Place, London, W.1, "The Viscosity of Liquid Hydro-Carbons," L. Grunberg, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., March 7th.—N.W. CENTRE: Engineers' Club, Albert Square, Manchester, "Lockheed Hydraulic Servo Systems for Heavy Goods and P.S. Vehicles," 7.30 p.m.——SCOTTISH CENTRE: North British Station Hotel, Edinburgh, "Steering Geometry and Wheel Balance," A. J. Hardman, 7.30 p.m.

Tues., March 8th.—MIDLANDS CENTRE: Crown Inn, Broad Street, Birmingham, "Some Trends in Vehicle C.I. and Petrol Engine Lubrication," F. Lawrence, 7.30 p.m.

Thurs., March 10th.—WESTERN CENTRE: Grand Hotel, Bristol, "Road and Rig Testing of Prototype Road Transport Vehicles and Their Components," J. Alden, 7.30 p.m.——E. MIDLANDS CENTRE: Mechanics' Institute, Nottingham, "Roads and Commercial Transport," G. Charlesworth, 7.30 p.m.——S. WALES GROUP: S. Wales Institute of Engineers, Park Place, Cardiff, Brains Trust, 7 p.m.

INSTITUTE OF WELDING

Mon., March 7th.—SHEFFIELD BRANCH: College of Commerce and Technology, Sheffield, "The Place of Radioactive Isotopes in Non-Destructive Testing," G. F. Gribbin and R. S. Forbes, 7.15 p.m.

Thurs., March 10th.—S. LONDON BRANCH: 2, Savoy Hill, London, W.C.2, "The Plurial Welding Process," M. Lebrun, 6.30 p.m.

Fri., March 11th.—EAST MIDLANDS BRANCH: Technical College, Lincoln, "The Economics of Welding," H. Martin, 7.15 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Wed., March 9th.—MIDLANDS BRANCH: The University, Edmund Street, Birmingham, "Instrument Performance in Industrial Applications," J. Illingworth, 6.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., March 8th.—Great George Street, London, S.W.1, "The Civil Engineer and Britain's Atomic Factories," D. R. R. Dick, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., March 7th.—INFORMAL MEETING: Savoy Place, London, W.C.2, "What is the Future of the Steam Locomotive?" opened by C. M. Cock, 5.30 p.m.——S. MIDLAND CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Short Circuit Testing of Turbo-Alternators," J. B. Young and D. H. Tompsett, 6 p.m.

Tues., March 8th.—LONDON STUDENTS' SECTION: R.E.M.E. Training Centre, Arborfield, Berks, "The Development of Fluorescent Tube Control," G. V. McNeill, 7 p.m.

Wed., March 9th.—RADIO SECTION: Savoy Place, London, W.C.2, "Artificial Reverberation," P. E. Axon, C. L. S. Gilford, and D. E. L. Shorter, 5.30 p.m.——N. SCOTLAND SUB-CENTRE: Caledonian Hotel, Aberdeen, "Special Effects for Television Studio Productions," A. M. Spooner, 7.30 p.m.

Thurs., March 10th.—EXTRA MEETING: Savoy Place, London, W.C.2, "The Electrical Equipment of the Toronto Subway Cars," F. W. Roberts, 5.30 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Mon., March 7th.—N.E. BRANCH: Northern Architectural Association Hall, 6, Higham Place, Newcastle upon Tyne, "The Launching of Ships," R. Allan, 7.15 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., March 8th.—39, Elmbank Crescent, Glasgow, "The Design of Cavitation-Free Ship Screws and Their Behaviour in the 'Behind' Condition," W. P. A. van Lammeren and J. D. van Manen, 7.30 p.m.

INSTITUTION OF ENGINEERS-IN-CHARGE

Wed., March 9th.—St. Bride Institute, Bride Lane, London, E.C.4, "The Use of Town Gas in Industry," A. E. Tyrrell, 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

To-day, March 4th.—Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Research in Soil Stabilisation," F. H. Maclennan, 5.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., March 9th.—Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, Annual General Meeting, "The Railbus," E. Kreissig, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, March 4th.—APPLIED MECHANICS' GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Practical Design Criteria for High-Speed Journal Bearings," Discussion, 6.45 p.m.

Tues., March 8th.—AUTOMOBILE DIVISION: GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, "Analysis and Interpretation of Service Records," A. T. Wilford, 5.30 p.m.

Thurs., March 10th.—INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP: 1, Birdcage Walk, London, S.W.1, Discussion, 6.45 p.m.——N.W. GRADUATES' SECTION: Engineers' Club, Albert Square, Manchester, "Production of Small Landing Craft at an Inland Works in Wartime," H. L. Trafford, 6.45 p.m.

Fri., March 11th.—AUTOMOBILE DIVISION GENERAL MEETING: 1, Birdcage Walk, London, S.W.1, James Clayton Lecture, "Heavy-Duty Truck Developments in the United States of America," Robert Cass, 5.30 p.m.——SCOTTISH BRANCH: Technical College, Dundee, "The Development and Scope of Work Study," R. M. Currie, 7.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Tues., March 8th.—ORDINARY MEETING: Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Some Non-Linear Magnetic Devices and Their Application to Telecommunications," J. W. McPherson, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, March 4th.—SOUTHERN BRANCH: Polygon Hotel, Southampton, Annual General Meeting, 8 p.m.

Mon., March 7th.—YORKSHIRE SECTION: Hotel Metropole, Leeds, Annual General Meeting and Lecture, 7 p.m.

Tues., March 8th.—DONCASTER SECTION: Danum Hotel, Doncaster, "Applications of Rubber to Engineering," J. P. Holdsworth, 7 p.m.——OXFORD SECTION: Town Hall, Oxford, "High-Frequency Heating and Brazing," E. V. Beatson, 7.15 p.m.——PETERBOROUGH SECTION: Campbell Hotel, Bridge Street, Peterborough, Annual General Meeting, Film Show, 7.30 p.m.

Wed., March 9th.—PRESTON BRANCH: Crown Hotel, Market Place, Blackburn, Annual General Meeting, "The Selection and Training of Engineering Apprentices," E. K. Langham, 7 p.m.

Thurs., March 10th.—LEICESTER SECTION: Balmoral Room, Bell Hotel, Leicester, "The Measure of Progress," F. G. S. English, 7 p.m.——N. IRELAND SECTION: Kensington Hotel, Belfast, Annual General Meeting and Informal Brains Trust, 7.30 p.m.——READING SECTION: Great Western Hotel, Reading, Annual General Meeting, "Industrial Law," H. P. Jost, 7.30 p.m.——ROCHESTER SECTION: Sun Hotel, Chatham, Annual General Meeting, "The Layout and Machinery Required for the Production of Clothing," W. Bland, 7 p.m.

Fri., March 11th.—EASTERN COUNTIES BRANCH: Diocesan Hall, Tower Street, Ipswich, "Symposium on Production Engineering Subjects," Annual General Meeting, 7 p.m.

INSTITUTION OF SANITARY ENGINEERS

Thurs., March 10th.—Caxton Hall, Caxton Street, Westminster, London, S.W.1, "Corrosion-Resisting Materials in Plumbing and Drainage for Chemical Works," R. T. Gillet, 6 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Tues., March 8th.—LONDON SECTION: "Oversea" League, Park Place, St. James's, London, S.W.1, "Changes in Rubber-like Materials by Exposure to High Energy Radiation," A. Charlesby, 7 p.m.

Mon., March 14th.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Abraded Tyre Treads," V. E. Gough, 6.45 p.m.——PRESTON SECTION: Bull and Royal Hotel, Church Street, Preston, "Inventions Still Needed to Provide Better Operation Control of Rubber Manufacture," H. C. Young, 7.15 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, March 4th.—Pepys House, 14, Rochester Row, London, S.W.1, Film Evening, 7 p.m.

Fri., March 11th.—ORDINARY MEETING: Pepys House, 14, Rochester Row, London, S.W.1, "The Rolling of Structural Sections," W. H. Bailey, 7 p.m.

Mon., March 14th.—SHEFFIELD AND DISTRICT SECTION: Livesey-Clegg House, Sheffield, "The Reconstruction of a Soaking Pit Building," K. H. Best, 7.30 p.m.

LIVERPOOL ENGINEERING SOCIETY

Wed., March 9th.—24, Dale Street, Liverpool, "The Technical Training of the Marine Engineering Officer," W. N. Serjeant, 6 p.m.

LONDON ASSOCIATION OF ENGINEERS

Sat., March 5th.—The Alliance Hall, Palmer Street, London, S.W.1, "Raising of H.M. Submarine 'Truculent,'" 6.30 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, March 4th.—Engineers' Club, Albert Square, Manchester, "Electronic Aids to Production," N. W. S. Ingles, 6.45 p.m.

NEWCOMEN SOCIETY

Wed., March 9th.—Science Museum, South Kensington, London, S.W.7, "Hand Wrought Chains," W. K. V. Gale; "The Vertical Winding Engines of Durham," G. M. Watkins, 5.30 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., March 11th.—Mining Institute, Newcastle upon Tyne, "A Comparison of the Total Weight and Bulk of In-Line Naval Gas Turbine Engines of Differing Degrees of Complexity," D. F. Collins and D. W. Thomas, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

Thurs., March 10th.—PRESTON BRANCH: Bull and Royal Hotel, Preston, "Structural Safety," A. G. Pugsley, 7 p.m.

ROYAL METEOROLOGICAL SOCIETY

Thurs., March 10th.—Conference Hall, County Hall, Westminster Bridge, London, S.E.1, "Clouds," F. H. Ludlam, 5.30 p.m.

ROYAL SANITARY INSTITUTE

To-day, March 4th.—SESSIONAL MEETING: The Guildhall, Kingston-upon-Hull, "The Water Supply of Kingston-upon-Hull—Past, Present and Future," T. H. Jones; Film, "An Epidemiological Approach to Health Education," William Ferguson and M. O. H. Beverley, 10 a.m.

Wed., March 9th.—LONDON SESSIONAL MEETING: 90, Buckingham Palace Road, London, S.W.1, "Co-operation Between Local Health Authorities and the Hospital Service: Possibilities and Actualities," W. G. Patterson and S. L. Wright, 2.30 p.m.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon., March 7th.—College of Technology, Pond Street, Sheffield, "The Place of Shell Moulding in the Foundry," B. H. C. Waters, 7.15 p.m.

SOCIETY OF INDUSTRIAL ENGINEERS

Sat., March 5th.—Building Centre, 425, Sauchiehall Street, Glasgow, "Practical Time Study and Effort Rating," J. Jones, 10 a.m.